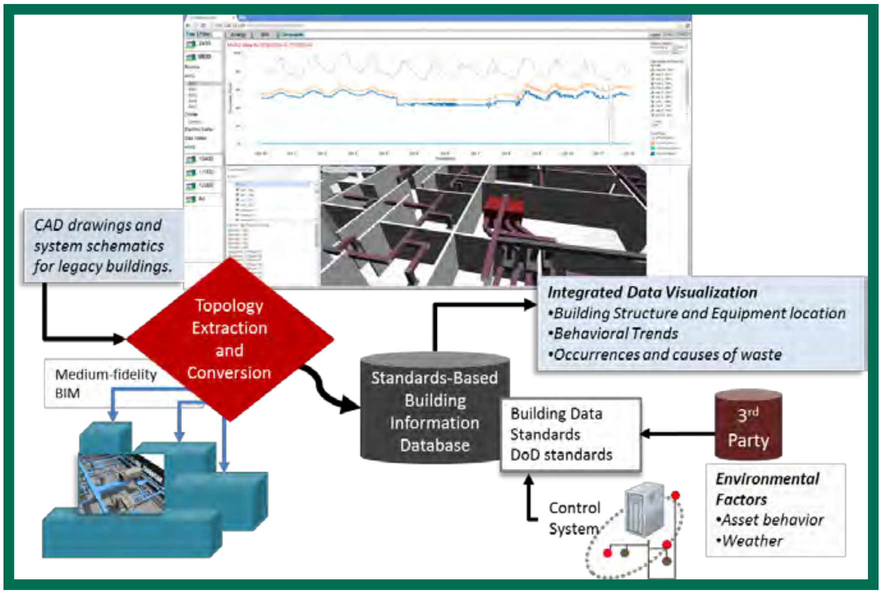
ESTCP
Cost and Performance Report

(EW-201263)



Model-Driven Energy Intelligence

March 2015

ESTCP

ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM

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14. ABSTRACT
This is the cost and performance report for Model Driven Energy Intelligence, ESTCP Energy and Water program 201263. This pilot program, at Fort Jackson, SC, illustrates the benefits of creating a retrofit building information model (BIM) for operations in legacy facilities. Five legacy buildings at Fort Jackson were modeled in 3D using a tool Honeywell has developed to create a medium-fidelity BIM from 2D CAD. We demonstrated that it is cost effective to generate this retrofit model using our methods, and that it may be used to deliver additional insight to support better energy and operation management. Model-Driven Energy Intelligence is the combined benefit of using the BIM to more automatically unite information about the physical facility with information about the behavior of the comfort and energy systems, and present that integrated view in a more intuitive manner. The report includes an overview of the costs of generating a BIM using the Honeywell BIMBuilder, and an estimate of the potential impact on energy performance at Fort Jackson.

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Building Information Modeling (BIM), Energy, ECMs, monitoring

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ACRONYMS AND ABBREVIATIONS

2-D	two-dimensional
3-D	three-dimensional
AHU	Air Handling Unit
API	Application Programming Interface
BIM	building information model
BLCC	Building Life Cycle Cost
BSR	Base Structure Report
BTU	British thermal unit
CAD	computer aided design
CERL	Construction Engineering Research Laboratory
CHW	Chilled Water
COBie	Construction Operations Building information exchange
COTS	commercial-off-the-shelf
DCS	digital control system
DDC	direct digital control
DoD	U.S. Department of Defense
DPW	Department of Public Works
DWG	Vector-based graphics file. A file name extension shown as .dwg
EBI	Enterprise Buildings Integrator
ECIP	Environmental Conservation Investment Program
ECM	electronically commuted motors
EISA	Energy Independence and Security Act
EM	Energy Manager
EO	Executive Order
ERDC	Engineering Research and Development Center
ESTCP	Environmental Security Technology Certification Program
FIPS	Federal Information Processing Standard
HBS	Honeywell Building Solutions
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	heating, ventilation, and air conditioning
HW	Hot Water
IFC	industry foundation classes
IR	Infrared
kWh	kilowatt hour

ACRONYMS AND ABBREVIATIONS (continued)

LAN	local area network
LOD	level of detail
MBTU	one million British thermal units
MDEI	model-driven energy intelligence
MDEI-DW	MDEI Data Warehouse
MDMS	Meter Data Management System
MEP	mechanical, electrical, and plumbing
MILCON	Military Construction
MT	Military Transformation
NIST	National Institute of Standards and Technology
NREL	National Renewable Energy Laboratory
OS	operating system
PO	performance objective
RTU	roof-top unit
SMS	Sustainment Management System
STIG	Secure Technical Information Guide
UI	user interface
UMCS	utility monitoring and control system
USACE	U.S. Army Corps of Engineers
VAV	variable air volume
WAN	wide area network
24x7	24 hours a day, 7 days a week

ACKNOWLEDGEMENTS

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- The U.S. Army Corps of Engineers (USACE) Engineering Research and Development Center (ERDC)- Construction Engineering Research Laboratory (CERL), Champaign, IL, for significant contributions to the program design and execution, and significant contributions to this report. Special thanks go to Tom Napier, Beth Brucker, David Schwenk, Joe Bush, Mariangelica Carrasquillo-Mangual, Justine Kane, and Lance Marrano.
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- The USACE, Savannah and Fort Worth Districts for access to Computer Aided Design (CAD) resources for some Fort Jackson facilities.
- The U.S. Army at Fort Hood for providing the Brigade Headquarters building as our Building Information Model (BIM) Builder test facility with our ERDC-CERL test subjects.
- The teams at National Renewable Energy Laboratory (NREL) and concept3D for their collaboration related to EW-201260.

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EXECUTIVE SUMMARY

Building information models (BIM) offer a multi-dimensional information structure and visualization tool for design, construction, and operations. The U.S. Department of Defense (DoD) has committed to applying BIM information standards and technologies for new construction and major retrofits. Engineering Research and Development Center (ERDC)-Construction Engineering Research Laboratory (CERL) analysis shows roughly 3.5% of all Army facilities have met the new BIM requirements; those designed and constructed between 2007 and 2012. All three DoD services now require BIM for new facilities. However, while BIM is revolutionizing the new construction process, the DoD is missing a large opportunity to reduce the total cost of ownership for their existing facilities by applying BIM to the long-term operation of their entire portfolio.

This demonstration set out to test three related hypotheses about the application of BIM to legacy facilities.

BIM BUILDER FOR LEGACY FACILITIES

Honeywell has developed a tool called BIM Builder, that imports computer aided design (CAD) [two-dimensional (2-D) vector graphics], and allows a user to selectively choose elements from those CAD drawings to generate a medium-fidelity three-dimensional (3-D) model of the facility, spaces, and related equipment, semi-automatically. BIM Builder and the resulting models are not meant to compete with tools such as Autodesk for new construction, but to address an unmet need for operations.

The goal of this project was to drive the variable costs (labor) of producing a BIM to \$1.00/100 square feet (ft^2). The results indicate that an average cost of \$.50/100 ft^2 can be achieved and that, as building size grows, this cost goes down. In the hands of a trained user, BIM Builder has the potential to generate a BIM for an arbitrarily large facility in a relatively fixed amount of time (2-4 hours on average).

SEMI-AUTOMATED CONTEXT DISCOVERY

Most building management systems produce a vast amount of information about the performance of buildings and equipment, including sensor data, equipment status, and scheduling. However, that data can be difficult to access for analytics due in part to the lack of supporting context, such as the proper name of the asset or the part of the building it affects. Quickly and cost-effectively finding and contextualizing the valuable data points has been a limiting factor to developing analytics tools that can deliver new value from data generated through digital control and monitoring of equipment.

Honeywell's Auto Context tool significantly reduced the manual effort of contextualizing raw telemetry from an existing system. Using this partially automated mapping method, the project team was able to complete the mapping of 847 points in under two hours, exceeding the performance goal. This lowers the barrier to utilizing more legacy data in the future.

MODEL-DRIVEN ENERGY INTELLIGENCE (MDEI)

By providing a means to put information about energy performance in context with the building structure and heating, ventilation, and air conditioning (HVAC) design, root causes for anomalous behavior can be more easily understood. Combined visualizations reveal the behavior of specific systems or subsystems that are affecting energy use in the facility.

The full Model-Driven Energy Intelligence (MDEI) system was installed at Fort Jackson, SC, and made available to the energy manager (EM) there. Monitoring was conducted for one full year; September 2013 through September 2014.

Detailed review of energy performance and the associated equipment behavior has led to the conclusions shown in Table ES-1 about the energy savings potential on the subject facilities.

Table ES-1. Estimated savings potential.

	Simultaneous heating and cooling	Continuous Operation	Incomplete Shutdown
Building Number	10400	2450	9810
Issues	Terminal unit behavior, including reheat and overall system operation	RTU behavior, and gas use for heating in vehicle bays	Scheduling anomalies
Solutions	• Improved scheduling • Retrofit improvements to air delivery to principal working space	• Improved scheduling • Additional automation on vehicle bay IR units	• Improved scheduling
Potential Savings (%)	18-25	15-25	15
Annual Savings (kWh)	340,255	341,616	175,121
Annual Savings (MBTU)	1161	1165	597

IR = infrared
kWh = kilowatt hour
MBTU = one million British thermal units
RTU = roof-top unit

Feedback from the energy manager at Fort Jackson, SC was positive; however, the circumstances of the deployment environment made it inconvenient to regularly access the data and integrate the tool in the normal workflow. These difficulties stem largely from the isolation of control systems on dedicated networks, and the difficulty of information integration across network boundaries.

ISSUES AND NEXT STEPS

BIM receives a great deal of attention for new construction, but the real asset management problem is the more than 90 percent of existing facilities, many of which will be managed for another 50 years. Long-term management of this information resource, both for newly constructed facilities and those with legacy data sources, represents a large gap in the understanding of how to better enable the DPW or the U.S. Army Corp of Engineers (USACE) to keep information about

facilities current and accurate with respect to facility and equipment condition. Aside from specific technology gaps, work processes and data management processes must also be addressed.

The availability of information about the real-time operation of facilities is another significant barrier to wide-spread application across the DoD. Network compliance barriers, information security policies, and a lack of instrumentation at many facilities will have an impact on the wide-spread deployment of energy monitoring solutions such as MDEI.

As DoD modernizes information management across its installations, there are opportunities to design for data quality and data management to support the long-term development and management of information resources so that they can be more readily exploited for further benefit to facility managers.

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1.0 INTRODUCTION

The majority of structures the U.S. Department of Defense (DoD) will need to manage over the next 50 years were designed with conventional two-dimensional (2-D) computer aided design (CAD) or paper draftsmanship and lack the digital, relational reference model a building information model (BIM) provides that enables dramatic productivity gains over the building life cycle.

The typical facility management operation is hard pressed to stay on top of day-to-day issues. Direct digital control (DDC) systems or utility monitoring and control systems (UMCS) are installed to execute and monitor the functioning of energy loads and comfort control systems in real time in some facilities. Complications stem from the proliferation of individual tools, a variety of vendor products, and specialized applications for energy management within and across DoD installations.

This pilot was designed to demonstrate an innovative and cost-effective method to generate a BIM-compliant contextual model, appropriate to a significant portion of the existing structures in the DoD portfolio (see Section 6.6). This medium-fidelity BIM, which focuses on the location and identity of assets for operations, rather than the precision and detail required for construction, provides a spatially-aware information structure to gather and more effectively utilize information about heating, ventilation, and air conditioning (HVAC) assets and their associated operating costs.

Information interoperability is a significant benefit of standards-based digital representation of building information. A gap analysis of interoperability of the information was provide from the BIM-based tools with other tools, including:

- simuwatt® Energy Audit, being piloted on the Environmental Security Technology Certification Program (ESTCP), Electronic Auditing Tool with Geometry Capture (EW-201260) (See Section 6.8.)
- The BUILDER Sustainment Management System (SMS) developed for capital management by the Army, and adopted by DoD
- The Construction Operations Building information exchange (COBie)

By using the physical information model provided by BIM, and attaching the operational information provided by the control system and metering, an energy manager and other interested stakeholders are provided with a ready source of rich information about how and why a building performs as it does, leading to better insights and more effective and timely energy management interventions.

1.1 BACKGROUND

BIM partially addresses the information integration problem for new construction, as the BIM mechanical model, combined with the architectural model, delivers a significant part of the missing context for the control telemetry, and the spatial context in which services are delivered. However, only about 3.5 percent of the Army facilities (as of 2013) have BIM models (see Section 6.4 for detailed analysis), and none are known to use them for operations today.

Honeywell has demonstrated that it is feasible and cost-effective to create a retrofit BIM for operations from CAD sources, and apply that BIM to drive improved energy awareness for facility management.

Potential Benefits

- *Fast BIM deployment:* BIM auto-generation technology will enable the DoD to use BIM in practice across the portfolio of existing sites with CAD source files. Life-cycle costs for BIM management are expected be lower due to fewer disparate tools and technologies required to generate models and the fact that BIM generation is partially automated. Further, when more applications can take advantage of a common model of the facility, the information management burden across these silos can be reduced.
- *Advanced analytics application:* Although significant energy savings can be obtained site by site without BIM, standardization to BIM semantics enables faster propagation of effective strategies from site to site and more comprehensive management across a portfolio. Standardization also allows for scalable design and easier integration of new sites into a DoD-level information architecture.
- *Effective energy-saving strategies:* With information from automation systems effectively connected to the context provided by BIM, identification and application of energy-saving strategies is more efficient and effective.

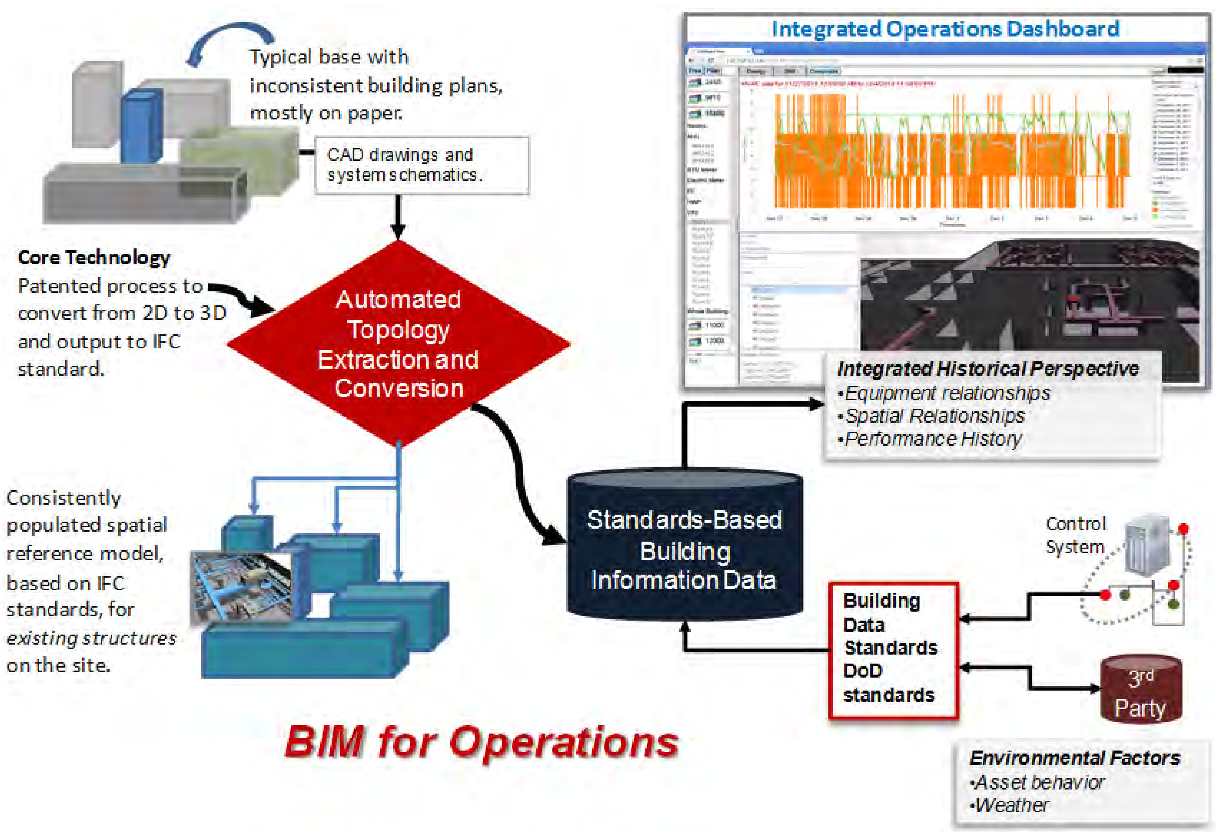

Figure 1. Conceptual overview of model-driven energy intelligence (MDEI).

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective for this program was to demonstrate that a retro-fit BIM can be produced cost-effectively, and that this standardized information model of the building and its assets can provide essential context to analyze and visualize data collected from control systems.

The program was designed to implement the following steps in information integration and presentation, to improve facility operations.

- ***Partially automate the generation of a BIM suitable for operations in a legacy building, by incorporating and transforming CAD data from a 2-D drawing to an industry foundation class (IFC) standard model.***

  Goal: Reduce the development cost of a BIM for operations by 80 percent.
  Result: The project team demonstrated that the tools are highly effective when sufficient CAD data is available. Applied to buildings of sufficient size and complexity in this pilot (>45,000 ft^2), the scalable approach exceeded the 80 percent cost reduction goal for BIM development. For smaller or less complex structures, the solution is comparable to prevailing BIM development techniques.

- ***Partially automate the correlation of data from legacy sources (e.g., control systems) to assets identified within the BIM.***

  Goal: Reduce the level-of-effort to map data from legacy systems by 50 percent or more.
  Result: The project team demonstrated automation that vastly reduces the manual effort for typical systems (those with some human-readable descriptions on exposed variables) and results in an average point identification success rate of 57.44 percent, and an average equipment identification success rate of 75.21 percent. This reduces the manual effort to identify interesting telemetry to manageable levels.

- ***Demonstrate the additional value that information fusion can bring to energy decision-makers through visualizations that provide rich context within an information model that is aligned to BIM concepts.***

  Goal: Increase the productivity of decision makers by at least 10 percent, as measured by number of buildings served or opportunities identified.
  Result: The study highlights specific benefits of data integration, but it was not possible to gather statistically-relevant data about the effect on energy manager productivity.

1.3 REGULATORY DRIVERS

Executive Order (EO) 13327: Section 3.b.ii.: This section prioritizes actions for improving the operations and financial management of the DoD’s real property inventory.

EO 13423: Section 2: This section is designed to help (a) improve energy efficiency and reduce greenhouse gas emissions of the DoD, through reduction of energy intensity by (i) 3 percent annually through the end of fiscal year 2015, or (ii) 30 percent by the end of fiscal year 2015, relative to the baseline of the DoD’s energy use in fiscal year 2003.

EO 13514: Sections 2.a.i, 2.g, 8.e and 8.f: This EO for federal leadership in environmental, energy, and economic performance requires that all new federal buildings achieve zero-net-energy by 2030.

Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding: Section I, II and IV. The principles of building commissioning (I) can be followed by adhering to BIM standards. Finally, by having detailed building energy system device data, specific aspects of indoor environmental quality (IV) can be tightly controlled, and energy performance optimized (II).

Energy Independence and Security Act (EISA), Public Law 110-140 (2007): The EISA of 2007 reinforces the energy reduction goals for federal agencies put forth in EO 13423, as well as introduces more aggressive requirements.

2.0 TECHNOLOGY DESCRIPTION

This section describes the technologies underlying the piloted solutions.

2.1 TECHNOLOGY OVERVIEW

The model-driven energy intelligence (MDEI) pilot made use of Honeywell-developed tools for generating building models and integrating data and contextual information into the model. The following paragraphs describe the BIM Builder, the Auto-Context semi-automatic context discovery system, and the MDEI user interface (UI) used to present the data and context.

2.1.1 BIM Builder

Honeywell developed an innovative system, BIM Builder, to generate a medium-fidelity BIM from legacy documents and information gathered about a facility. The generated BIM adheres to IFC standards of description but is focused on identifying a specific subset of data for operation and maintenance of building services, rather than a detailed and precise plan for construction.

Figure 2 illustrates the BIM Builder approach, which largely automates the population of the basic geometry and the recognition of significant concepts, such as those identified by COBie and other standard data sets; it combines those data into a unified building context—without the need for draftsmen or hours of manual data entry and manual validation.

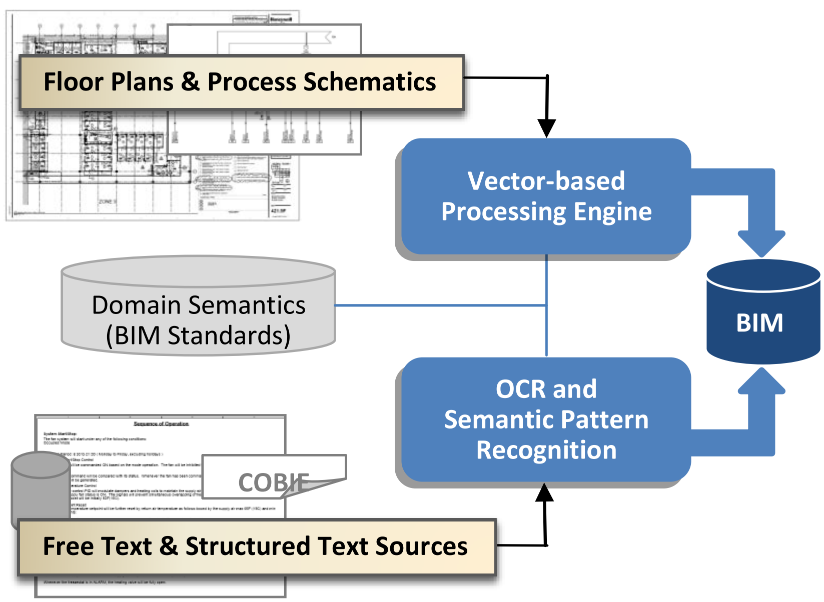

Figure 2. Identification and extraction of building context into BIM.

Honeywell invested in technology to extract 2-D geometry and match elements to the domain semantics provided by the IFC, and then convert them from 2-D to three-dimensional (3-D) geometry. This innovation is significant, because most 2D geometry sources describe only a set of vectors that have no semantic description and have neither type nor identity. Figure 3 illustrates this process.

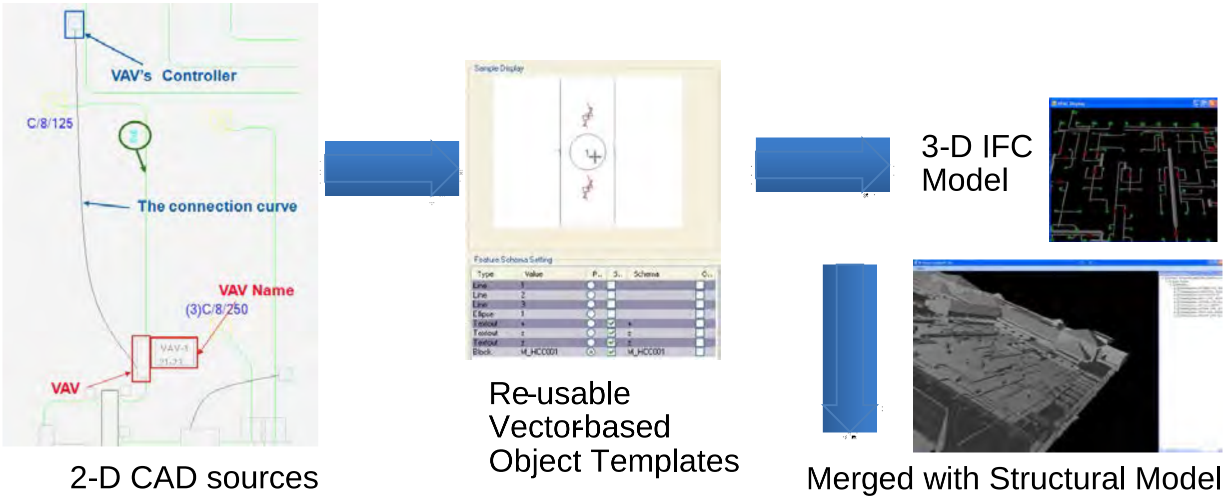

Figure 3. Process overview for the partially-automated development of BIM from CAD.

Further context and network structure can be extracted through semantic matching from other text and electronic sources of information about the site, including the control system. Employing data fusion techniques can improve both the accuracy and content of the automatically-generated BIM.

The generated BIM (Figure 4) can be IFC and COBie compliant, thus making the data content of the model available to any system using these standards (e.g., AutoCAD, Revit, BIMserver, and other commercial and open-source tools).

Figure 4. Generated BIM for Fort Jackson facility.

2.1.2 Automatic Context Discovery for Control Information Integration

Data available from building controls can provide very specific insight into how building systems are behaving and what impact the behavior of individual assets may be having on occupant comfort or energy use. Unfortunately, this data can be hard to access for regular and repeated evaluation by an EM.

Honeywell developed the Auto-Context application to leverage patented algorithms and techniques, to classify and map digital control system (DCS) points to common categories and to

identified assets (equipment) using a partially-automated process which leverages semantic standards.

Algorithms identify and map the unique tokens in the local naming convention, according to domain rules. The results are queried against a standard set of system aspects to find the best matching description of the point and its role. The process is robust to most control system types, so long as some human readable description or name is present for processing. The result is a scalable solution that reduces the manual effort of contextualizing the raw telemetry from an existing system.

2.1.3 MDEI User Interface

The facility manager or energy manager typically uses a vendor-specific console to access process trend data, and they can also turn to CAD drawings or their recall of a facility, or in rare cases, a complete BIM. While these sources of data have been available to energy managers for some time, they can rarely be referenced simultaneously for a complete picture of building operations or for easy, regular viewing; it is not typical to have on-demand access to integrated information.

Using the physical information model provided in the BIM and attaching the operational information provided by the control system (through the Auto-Context discovery process), can provide rich information about how and why a building performs as it does. The MDEI UI provides the navigation environment that the energy analysts and EM utilized to access BIM and energy information, as shown in Figure 5.

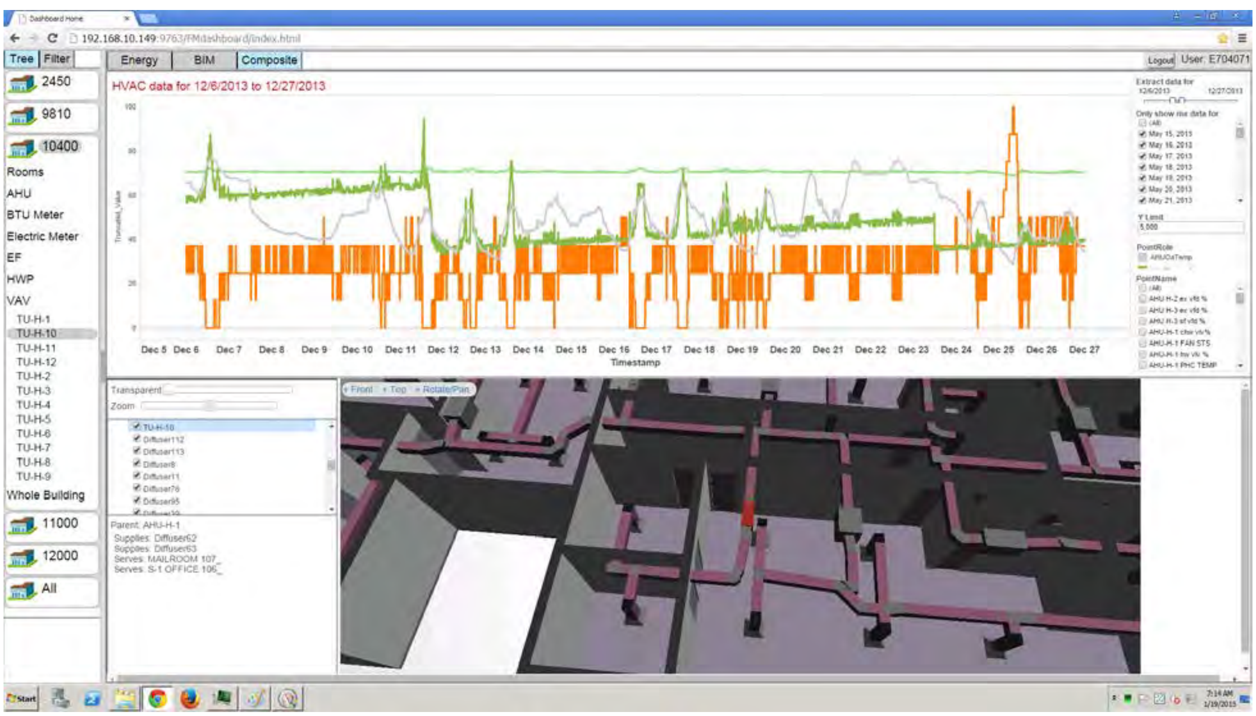

Figure 5. Integrated view of BIM and UMCS data in the MDEI UI.

2.2 TECHNOLOGY DEVELOPMENT

The BIM Builder tool is the result of several years of investment by Honeywell. No DoD funds were used in the development of this tool. However, as the project team encountered issues with the CAD files received for pilot sites at Fort Jackson, Honeywell funds were used to improve BIM Builder to address the requirements that were made evident in the DoD CAD sources.

Processes and algorithms for automated context discovery were developed by Honeywell prior to the pilot, and exercised on data from the Fort Jackson facilities. No program funds were spent on the development of this approach.

Prior to deployment, Honeywell configured a pilot-specific web environment for navigation of the data made available to the energy manager. The details of this pilot dashboard (Figure 5) for MDEI are provided in Section 5. The architecture of this web-based application is fully explained, and the provided visualizations are also described. For the most part, the team used commercial-off-the-shelf (COTS) tools to construct this dashboard, providing the final linking mechanism between sources of data to be integrated for the energy manager.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

Process Requirement: Generating a medium-fidelity BIM suitable for energy and asset management for operations, for legacy facilities.

- Most typical current practice: Someone familiar with commercial 3-D BIM modeling tools can use legacy CAD drawings as an underlay to place objects in a new 3-D model. These objects must also be manually identified and labeled.
- MDEI Approach: The project team semi-automatically extracts the necessary contextual information about spaces and equipment from 2-D CAD using BIM Builder, including the names or labels embedded in the CAD source, and express this information using BIM standard representation IFC.
- Advantages: The BIM Builder tool and methodology reduces the cost to model very large facilities due to economies built into the automation. Modeling efficiency improves as the size of the building to be modeled increases. Using a common description for the building makes this data more widely available for multiple purposes.
- Limitations: On buildings under 45,000 ft^2, the BIM Builder method may be equal in processing costs to using the typical current practice of placing objects using commercial 3-D tools. The effectiveness of BIM Builder can be affected by the quality and validity of the CAD sources that are available. For buildings with no CAD in .dwg (digital) format, this process can't be applied.

Section 6.1 in the Final Report discusses the related technologies, pilot activities and findings.

Process Requirement: Identifying and mapping data about equipment behavior and performance from legacy DCS and associating that data with named assets and spaces.

- Most typical current practice: Someone familiar with the building and the energy management problem must manually comb through the available data sources, and document the relationships between each data point and the related equipment and/or spatial assets that describe its context.
- MDEI Approach: The project team semi-automatically extracts the necessary contextual information about spaces and equipment from the naming conventions used by the DCS at the site. AutoContext assists the user in quickly associating this data to the right assets as identified in the BIM.
- Advantages: Using AutoContext can significantly reduce the manual effort of sifting through large numbers of possible variables exposed by control systems to quickly identify and link the useful data for energy and asset management. The process is not dependent upon having a BIM, so it can be used in any case that entails classifying large quantities of DCS data that is not well described.
- Limitations: Some DCS are deployed with naming conventions that cannot easily be addressed by automation, such as those that use numbers as identifiers, or those that make heavy use of single characters in the naming convention. See Section 6.4 of the Final Report for further discussion of these issues.

Process Requirement: Identifying the root cause of unusual energy use in a facility.

- Most typical current practice: Someone familiar with the building and the energy management problem must review data from several sources and several systems to collect the information necessary to troubleshoot. Usually, this process starts with whole building energy and then progresses to investigation of how the DCS is programmed to manage comfort and energy. Sometimes it requires looking at CAD drawing of the building or visiting the building to obtain enough information to understand underlying causes.
- MDEI Approach: The project team brings together all the information sources that an energy manager can use to troubleshoot causes of energy waste or other operating problems in a building, into a single, browseable interface for easier remote investigation.
- Advantages: By using BIM as a means to integrate, navigate, and understand the relationships between the equipment and spaces, it is possible for the energy manager to easily connect performance issues with specific behaviors occurring in the facility, and to immediately see anomalies in system operations that might be hard to discern otherwise. The data from all these sources is unified by using the physical model to aid understanding, and mask the vendor-specific implementation differences that can make investigations more difficult.
- Limitations: The solution can only deliver value when it becomes an integral part of the energy management process. Network issues, information management requirements, and isolated legacy control infrastructures are significant barriers to integrating data into a single environment. Appropriate 3-D navigation interactions still need to be addressed for casual users of 3-D models. The default behaviors of the available COTS tools employed in this pilot are not optimal for the use cases demonstrated in this effort. These issues are discussed further in Sections 5, 6.2, and 6.3 of the Final Report.

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3.0 PERFORMANCE OBJECTIVES

Table 1 and Table 2 present the quantitative and qualitative performance objectives along with the performance metric and the success criteria for each of the identified objectives. In every case, more detailed results are provided in Section 5 (data collection and metrics) and Section 6 (detailed performance results) of the Final Report.

Table 1. Quantitative performance objectives.

Metric	Data Requirements	Success Criteria	Results
PO1: Produce a functional BIM for operations through a semi-automated generation process.			
Level-of-detail (LOD)	Assessment against LOD requirements for energy management use cases. 2-D CAD floor plans and MEP drawings.	BIM supports the data required for specified energy management use cases. These use cases are described in Section 6.1 of the Final Report.	The expected LOD goal was met. However, the evaluation conducted by the ERDC-CERL team revealed some required improvements to IFC export to support data integration using IFC and COBie. See Section 6.1 and Appendix F of the Final Report.
PO2: Asset-level energy intelligence impacts energy use in managed buildings.			
Meter data (BTU/ft^2, or kWh/ft^2)	Asset and system performance data; meter data at building/asset level. Duration of each abnormal energy use event. Re-occurrence of abnormal energy use events. Track use of tool, and logged identification of issues.	Reductions in energy use by 10-20% from existing baseline use, due to faster and improved responses to abnormal energy use patterns.*	It was estimated that it is possible to achieve 15% or better energy intensity reductions based on observed behaviors described in Section 6.2 of the Final Report, however, no substantial remediation was taken as a direct result of the project team's recommendations during this program. Therefore, the resulting savings have been estimated.
PO6: Partially automated identification and standardized classification of control points.			
Time required to correctly classify 500 points relevant to advanced analytics	Control system points with typical inconsistency in naming such as the use of capital/lower case, the use of spaces or special characters as concept delimiters, and inconsistent concept abbreviations (e.g., Bldg1_AHU3_RetTemp and B1_AH4RATmp have the same classification but are inconsistently identified).	Enable correct identification and classification of pertinent telemetry from one or more buildings within 4 hours.	It was demonstrated that AutoContext can be used on systems with wide variation in naming conventions to significantly reduce the manual effort required to identify and map points for use in energy management. The goal of mapping 500 points of interest in less than 4 hours was met, and the project team expects that this approach can be improved upon.

* Since Honeywell can't control whether energy savings measures are actually implemented, the identification of actionable energy savings practices from implemented energy savings practices is separated.

BTU = British thermal unit
CERL = Construction Engineering Research Laboratory
ERDC = Engineering Research and Development Center
kWh = kilowatt hour
MEP = mechanical, electrical, and plumbing
PO = performance objective

Table 2. Qualitative performance objectives.

Metric	Data Requirements	Success Criteria	Results
PO3: Improve energy manager visibility into building performance data.			
Percent of pilot buildings reviewed per month using BIM and energy data	Quarterly user interview to assess frequency of viewing and value of information. Note resulting actions.	Building energy usage reviewed monthly using BIM and performance data; information perceived as useful.	The energy manager did not regularly review the buildings. The reasons for this are discussed in Section 6.3 of the Final Report.
PO4: Transferability of conservation measures to other like assets.			
Number of assets that are candidates to benefit from monitoring for a specific operating anomaly	DPW response about the benefits and feasibility to implement the monitoring methods for other buildings at the installation. Catalog asset inventory to assess transferability of energy measures to other similar assets across DoD.	In at least 50% of cases, a monitoring approach can be applied to at least 50% of similar monitored assets in DoD Facilities. The team concluded that roughly 69,000 DoD facilities of the 176,000 total that require conditioning could benefit from monitoring for the noted ECMs.	According to the analysis conducted by ERDC-CERL on DoD active inventory, approximately 40,000 existing facilities, or those expected to be constructed in the next few years, are likely candidates for the demonstrated approach. These are buildings of sufficient size. They are likely to have CAD or BIM, and digital control, and benefit from the ECMs applied in this pilot. This is slightly more than half of the potential candidates for monitoring.
PO5: Efficiency of the BIM tools for effective site survey and Medium-fidelity BIM generation.			
Square feet of buildings per hour of BIM developer time	Productivity data: Tracking in the BIM tool to monitor rate of completion. Self-reporting by users. Survey and observe users.	An experienced user produces the BIM at ~20% the typical cost of a BIM produced by traditional means (Brucker, 2009). Section 5.1 of the Final Report discusses adjustment to this criterion.	The goal was to drive the variable costs (labor) of producing a BIM to \$1.00/100 ft^2. Results indicate that on average \$.50/100 ft^2 can be achieved, and that as building size grows, this cost goes down.
PO7: Conduct gap analysis of the content and quality of data represented in the generated BIM with respect to BUILDER database			
LOD and consistency of data with BUILDER data requirements	Generated BIM BUILDER data definitions or templates for data collection.	Demonstrate that the generated BIM data is an appropriately defined subset of the data required for BUILDER objectives and can be used to populate BUILDER data fields.	The investigation conducted by ERDC-CERL revealed shortcomings in the export format of the information collected in BIM Builder. Honeywell estimates that these issues can be remediated at low cost to support direct compatibility.

BIM = building information model
CAD = computer aided design
DPW = Department of Public Works
ECM = electronically commuted motors
LOD = level-of-detail

4.0 FACILITY AND SITE DESCRIPTION

4.1 FACILITY AND SITE LOCATION AND OPERATIONS

Fort Jackson is a large Army post near Columbia, South Carolina, with a primary mission of training. There are more than 1000 buildings within the developed regions of the Fort. Keeping buildings running consistently is particularly challenging because a large part of the population is transient. While Fort Jackson's energy conservation goals require a decrease of 3 percent in energy demand year-over-year, their actual energy intensity is not contracting at a pace to meet this goal. From 2007 to 2009, the site's total energy consumption (one million British thermal units [MBTU]/1000 ft^2) consistently increased year-after-year, exceeding baseline levels set in 2003.

In addition to command support from the Fort Jackson DPW, there was on-site support by Honeywell staff under contract for energy services at Fort Jackson.

In cooperation with the Fort Jackson EM, the team selected five buildings on the Fort that could support demonstration objectives, and were interesting for the purposes of this pilot. The buildings selected for this demonstration are listed in Table 3.

Table 3. Selected buildings at Fort Jackson.

Building Number	Building Usage Category	Building Automation System	Estimated Area (ft^2)	CHW Source	HW Source
11000	Barracks	Honeywell	290,481	Plant 2/ Zone 2	Plant 2/Zone 2
12000	Barracks	LonWorks	290,481	Plant 2/ Zone 2	Plant 2/Zone 2
10400	Office/Admin	iNet™/TAC	23,178	Plant 4	Plant 4
2450	Maintenance	Honeywell	125,000	AC Units	Stand-alone
9810	Office/Admin	Honeywell	37,310	Stand-alone	Stand-alone

CHW= Chilled Water
HW = Hot Water

These five buildings provided a good cross-section of the various types of facilities on the Fort, and a cross-section of legacy technologies.

4.2 FACILITY/SITE CONDITIONS

There were some significant building data collection issues evidenced in the data quality figures reported in Section 5.6 and elaborated in further detail in the Final Report. Table 4 summarizes the last status of utility metering on the subject buildings as of September 1, 2014.

Table 4. Meter data availability at pilot facilities.

Building Number	Gas Meter	Electric Meter	BTU Meter	CHW Data	HW Data
2450	Good	Good	n/a	n/a	n/a
9810	Stopped reporting	Good	n/a	n/a	n/a
10400	n/a	Good	Good	Temps only	Pump Status, Temps
11000	Bad Data	Good	Good	Pump Status, Temps	Pump Status, Temps
12000	Not Available	Not Connected	Good	Pump Status, Temps	Pump Status, Temps

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5.0 TEST DESIGN

This demonstration was intended to show a practical way to create and manage BIM for legacy building management at a reduced cost, and use it to make data more readily available to enable effective energy management. The test design is grouped around two overarching questions related to the performance objectives.

5.1 CONCEPTUAL TEST DESIGN

Q1: Does the BIM Builder tool reduce the cost of generating a useful medium-quality BIM as compared with traditional means?

Hypothesis

The BIM Builder will produce a medium-quality BIM at approximately 20 percent of the typical cost (Brucker, 2009) of delivering a retrofit BIM with a comparable level of fidelity. It was further expected that BIM Builder would produce a medium-quality BIM more quickly and more accurately than other techniques.

Test Design

Conceptual testing was designed to show that the tools being piloted support the generation of a BIM that: 1) can be generated at a low cost, with sufficient detail and accuracy to support energy management use cases; 2) is consistent with BIM standards and can be exchanged with other tools that use BIM standards; and 3) delivers information that can be readily utilized for DoD asset management.

Test Phases

Phase I: BIM generation: The outcome of this task was the collection of all necessary data, requirements, and artifacts, including CAD source files, necessary to construct the BIM, initial models for the site, and statistics related to the time and cost for BIM generation.

Phase II: BIM validation: The outcome of this step was a validated functional BIM for operational use for each of the pilot facilities, with all gaps assessed and addressed. The output of this phase is the basis for analysis in Sections 6.1 and 6.5.

Phase III: Enhance BIM with building automation references: The outcome of this task was a fully representative, BIM-consistent model of the data to be used for analysis and visualization. Findings related to this phase are elaborated in Section 6.6.

Phase IV: Assessment of efficiency of the Honeywell BIM Builder tool with representative DoD employees: The BIM Builder tool was exercised in a controlled setting with ERDC-CERL participants. The findings of this exercise are described in Section 6.5. During this phase, the project team recognized that comparison to the results of the previous study (Brucker, 2009) was not appropriate, and therefore adjusted the comparison criteria to evaluate BIM Builder against current practice with conventional BIM tools.

Phase V: Assessment of transferability of BIM data to BUILDER SMS: The outcome of this task is an evaluation by ERDC-CERL of the means by which BIM data may be used to populate required BUILDER data. Details of this evaluation are provided in Section 6.7.

Phase VI: In collaboration with ESTCP 201260, the teams examined the potential of integrating these complementary solutions to improve the ability to generate spatial reference models for buildings of any age—with or without existing documentation of the architecture and assets. Results of this phase are documented in Section 6.8.

Dependent Variables: Time expended to produce a BIM (with a specified degree of detail), measured in ft^2/hr.

Independent Variable: Tool or method used to create a retrofit BIM.

Controlled Variables: User competency, and complexity of the site to be modeled

Q2: Does providing BIM-driven visualizations provide enough context around energy usage and spend to drive action to reduce energy waste?

Hypothesis

Buildings equipped with BIM-driven visualizations of energy spend data will experience a reduction in energy waste by 10 percent in comparison to the energy spend before being equipped.

Test Phases

Phase I: Research & Requirements: The team conducted interviews with the energy manager and other DPW staff, as well as individual building managers to assess their requirements and how to best engage these individuals during the pilot. The output of this phase is the basis for analysis in Section 6.3.

Phase II: Facility Energy Baselines (Pre-Test): Details of baseline analysis on collected energy data are provided in Section 5.2.

Phase III: Visualization Review: The Honeywell team reviewed the energy visualizations and analyses with the energy manager at Fort Jackson and other team members to collect feedback on the usefulness of the contextualized data and the validity of the observations.

Phase IV: Facility Energy Usage (Post-Test): Follow up conversations were conducted with the energy manager to assess the utility of the information and the impact on energy management activities. The output of this Phase III and IV is the basis for analysis in Section 6.2.

Dependent Variables: Energy meter data and equipment run time

Independent Variable: BIM-driven data visualization

Controlled Variable: Building properties

5.2 BASELINE CHARACTERIZATION

This section describes the data that was available for baseline characterization in each facility, and the results of baseline analyses. Since no new energy strategies were being applied at any of the facilities during the pilot period, some baseline characterizations include the entire body of collected data normalized by heating or cooling degree days.

Due to the difficulty in getting data for some of the facilities, complete baselines and further energy analyses are provided for only three of the five pilot facilities.

Figure 6 provides a normalized view of the total intensity of energy use across the pilot facilities. Gas meter data is not available for building 9810, so its actual energy intensity is even higher with respect to the other two facilities. Energy intensity for building 2450 during the cooling season appears unusually low because only 45,000 ft^2 of the 210,000 ft^2 facility is cooled.

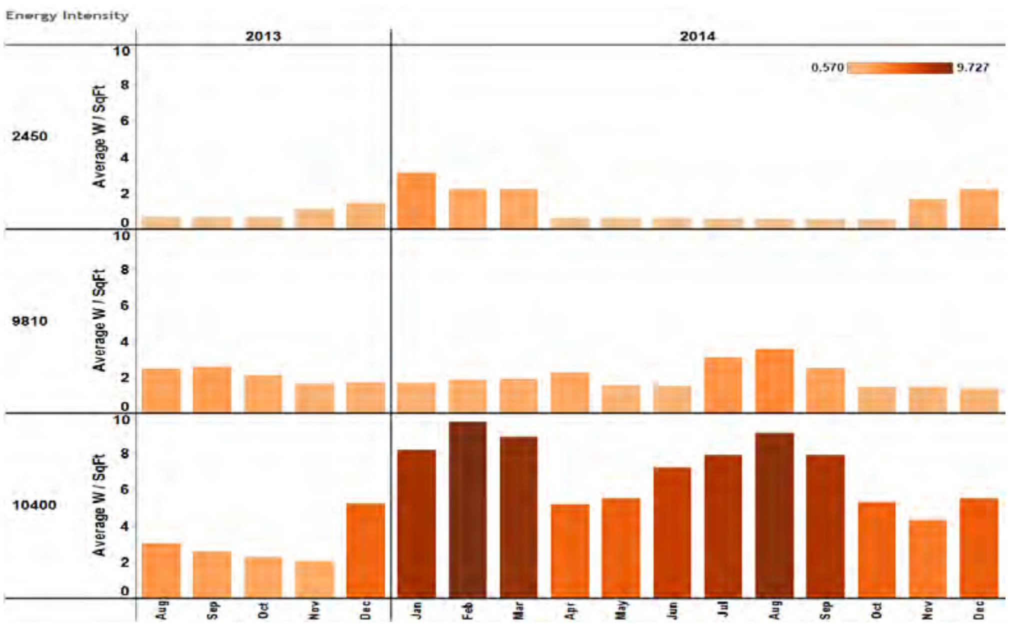

Figure 6. Total energy intensity in average W/ft^2.

Figure 7 shows the same information, but exposes the different energy sources for each site. Here, the missing gas data for 9810 is noticeable. 10400 is the only building in this set that uses Hot Water and Chilled Water from centralized plants at Fort Jackson. The Hot Water meter at building 10400 did not start reporting until January 2014.

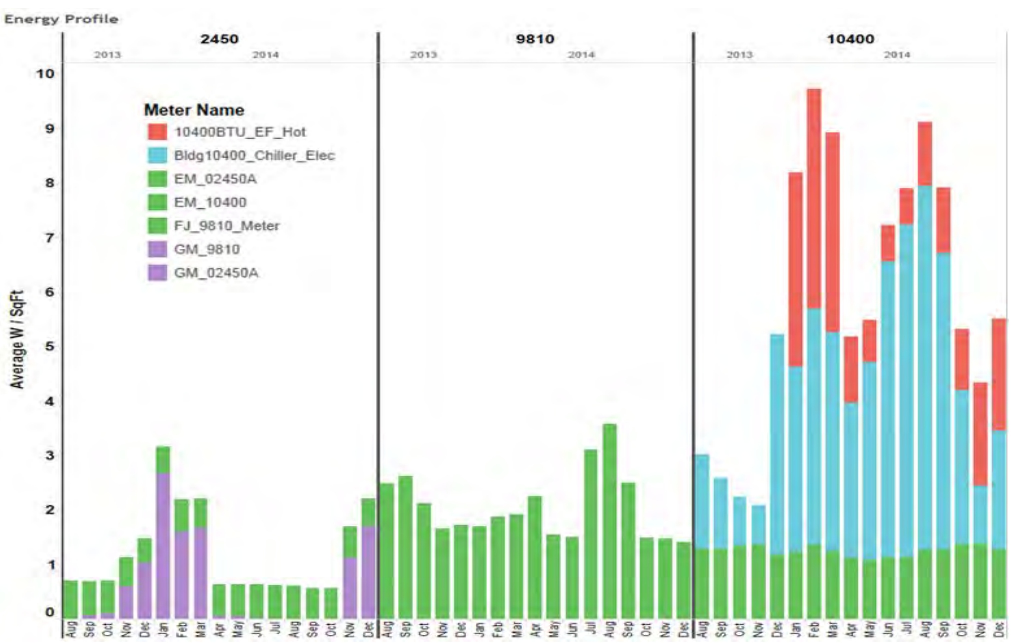

Figure 7. Energy intensity by constituent energy sources at each facility.

5.2.1 2450 Vehicle Maintenance School Baseline Assessment

The vehicle maintenance school is a cement-block facility built in 1987 that contains 45,000 ft^2 of classrooms and offices with heating and cooling provided by three rooftop units which were refreshed in 2011. It also has five large vehicle maintenance wings comprising 75,000 ft^2, with cold weather infrared (IR) heating apparatus and heavy duty exhaust fans operated mostly during the heating season.

The energy baselines indicate that some scheduling (adjustment of HVAC services based on building occupancy) is applied, but is not as effective as it should be. Large spikes in gas use and 24-hour activity suggests that IR units are not always shut down when the vehicle bays are not in use. Base loads drop well below the regression curve suggesting that the building HVAC systems could be shut down much more effectively to achieve a better base load during non-occupied periods.

5.2.2 9810 Soldier Services Building

The Soldier Services facility is a split-level, concrete-block structure built in 1975 which houses multiple tenants in office spaces totaling 37,210 ft^2. Originally this facility had five air handlers, which provided air through zoned ducts without terminal units. During the pilot in 2014, large parts of the air conditioning system were being refreshed by another third party.

Energy profiles indicate that some scheduling is in place because systems shut down in the evening, but restart and run all night long. Energy use shows a high degree of weather dependency, 24 hours per day, 7 days per week (24x7). However, the analysis indicates a wide variation in energy loads that would not be anticipated given this type of facility and operation.

It is possible that some of these service organizations offer support 24x7 to soldiers in need. It is not likely that these services encompass the entire facility.

5.2.3 10400 Barracks Administration Offices and Classrooms

The Barracks Administration facility was built in 2005. Two large classrooms and an office space are housed in this 23,178 ft^2 facility. Each classroom has its own air handler and a third serves the balance of the facility including all office spaces. This facility is served with Chilled Water and Hot Water from central plants.

The energy intensity of this facility is significantly higher than would be expected for a building of this age and design. The energy patterns indicate that the entire building is operated to the same requirements 24x7, including class rooms, with no scheduling for occupancy or weekend operations. There is significant electrical load in moving air through the facility 24x7. Analysis of the heating and cooling demands on the central plant illustrate a high degree of simultaneous heating and cooling, and relatively high energy intensity for operations year-round, with no clear weekday or weekend pattern.

Casual observations while visiting the site indicate that classroom occupants use the egress doors on the classrooms to moderate temperatures (classrooms are considered too cold). This uncontrolled introduction of outside air most likely has an influence on performance.

5.2.4 11000 Barracks (Starship design)

This 290,400 ft^2 barracks was constructed in 1987 and extensively remodeled between 2010 and 2011. A large, single-story, central space provides extensive classroom facilities and a small front office area for administrative personnel. Five, two-story, elevated U-shaped barracks extensions provide office and living space for each cadre housed in the barracks. The spaces are conditioned by 29 air handlers installed throughout the facility and on the rooftop, which consume Chilled Water and Hot Water from central plants.

Due to significant issues with data quality from 11000, no baseline measures can be provided. There were substantial data drops from electrical, gas, and BTU metering because of incomplete meter commissioning. Further missing data from unsupervised controllers on significant HVAC loads left no means to provide accurate baseline analysis.

It is useful to note here that 11000 and 12000 are contemporaries at Fort Jackson, built and remodeled in the same timeframe, yet they are substantially different in their spatial and HVAC configuration. This observation is an important footnote to expectations for any consistency across buildings of similar age and even similar design across the DoD.

5.2.5 12000 Barracks (Starship design)

This 290,400 ft^2 barracks was constructed in 1987 and extensively remodeled between 2010 and 2011. The allocation of space is the same as in 11000, but the arrangement of spaces and HVAC support are very different. The spaces are conditioned by 15 air handlers installed throughout the facility and on the rooftop, which consume Chilled Water and Hot Water from central plants. Though they were remodeled at a similar time, 11000 and 12000 have significantly different floor plans in some portions of the facility, and very different air handling solutions.

Due to significant issues with data quality from 12000, no baseline measures can be provided. Substantial data drops occurred for both electrical, gas and BTU metering because the meters were incompletely commissioned. As with 11000, further missing data from unsupervised controllers on significant HVAC loads left no means to provide accurate baseline analysis.

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

The following subsections provide an overview and summary of the technology and design of the MDEI supporting architecture. Some new components were added to the Fort Jackson Energy Center infrastructure to support this project while also utilizing existing technology.

5.3.1 System Design

The principal technical components of the MDEI Server architecture include the following commercial products: Dell™ Server Hardware, Windows® Server 2008 Operating System (OS), Microsoft® SQL Server 2008, Apache Tomcat web server and Tableau® Server. Each of these

solutions has applicable Security Technical Implementation Guides (STIG), which can be applied to make them suitable for deployment in a secure DoD environment.

Additionally, Honeywell Enterprise Buildings Integrator (EBI) and Honeywell Energy Manager were used to facilitate the collection of DCS and meter data. These commercial solutions are already approved and employed at the site for similar purposes.

The final component is a standard Windows OS Desktop system, procured as part of this contract, and installed within one of the EM's workspaces. The system is connected to the Energy Center local area network (LAN) using an existing wireless network, previously approved for remote access to the Fort Jackson Energy Center, for the purposes of access to the installed supervisory control systems. Figure 8 illustrates the system architecture.

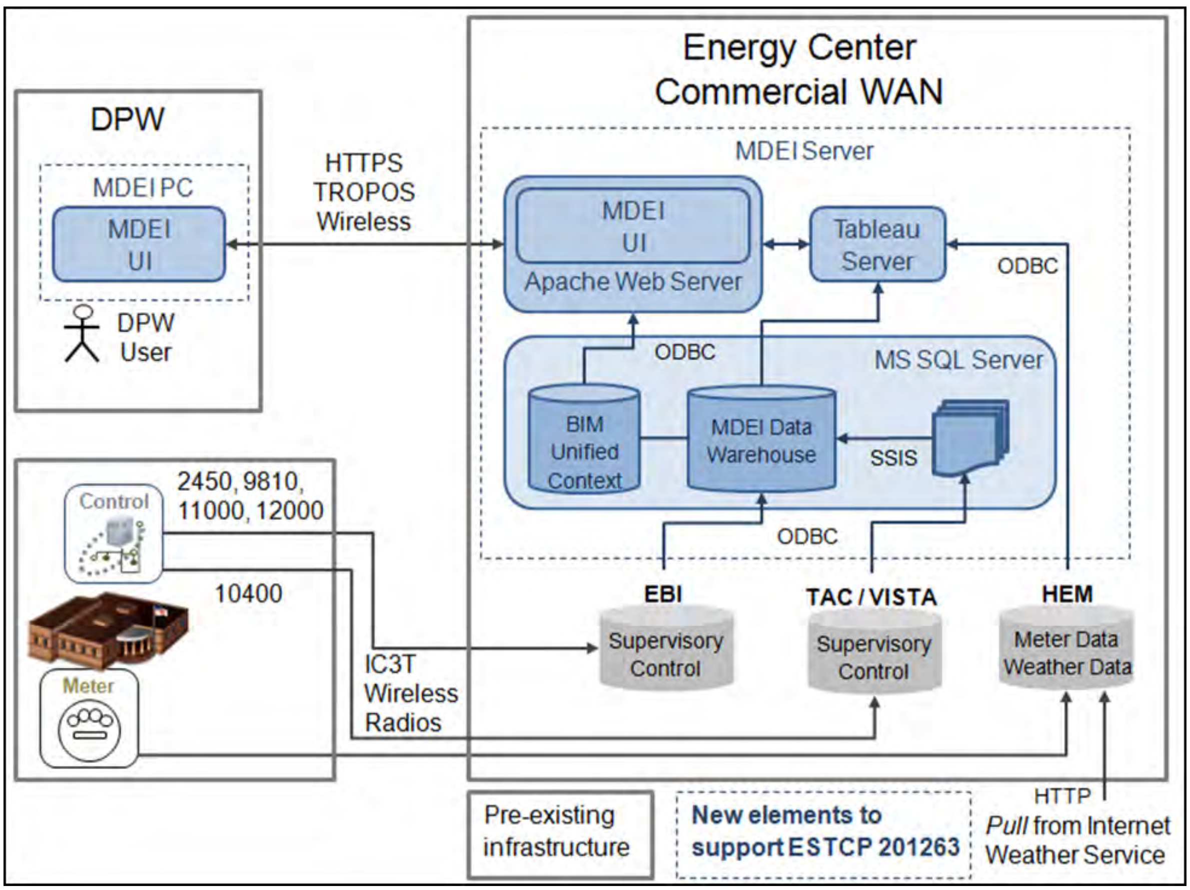

Figure 8. System architecture and communications.

5.3.2 System Communications

The Honeywell Energy Center is positioned within two local networks that host the metering devices and some building automation solutions, as well as Honeywell Energy Manager and EBI. The local Energy Center network collects data from sites on the base using approved wireless networks that meet the DoD requirement for Federal Information Processing Standard (FIPS) 140-2; The buildings selected for this project have control systems reporting across these local networks. Figure 9 is a diagram of the network.

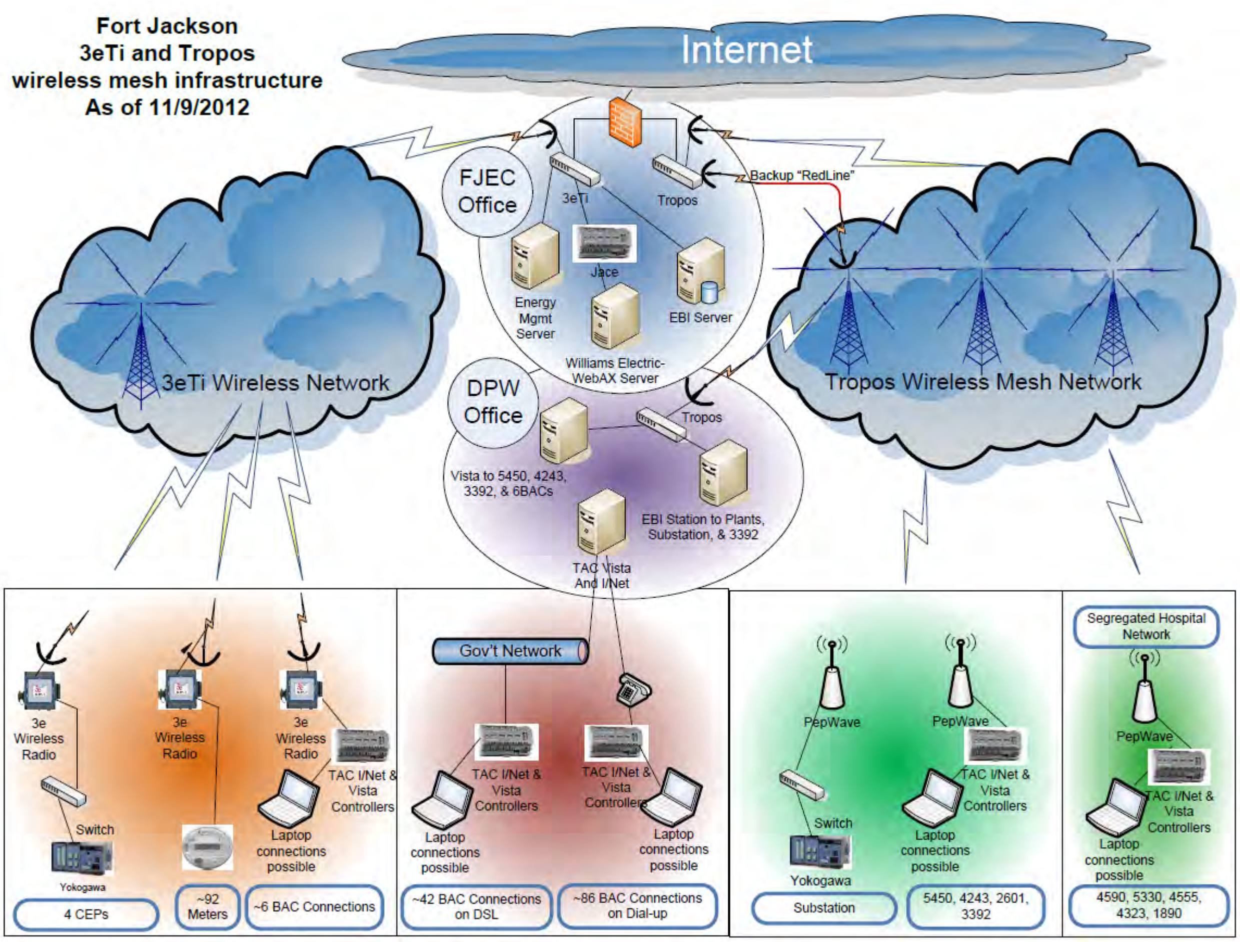

Figure 9. Network infrastructure through Fort Jackson energy center.

5.3.3 System Components

MDEI UI: The MDEI UI supports uniform access to all the data collected about each of the facilities, regardless of which system produced that data. Data-driven navigation is dynamically constructed based on the spaces and assets identified by the BIM. It supports the user in selecting the scope of interest. Since the menus are built dynamically using the underlying BIM data stored in a database, the UI does not need to be rebuilt when additional buildings are added to the ecosystem.

Figure 10 illustrates the various elements that make up the UI infrastructure. The interface is completely web-enabled, served through an Apache Tomcat web server, with basic page elements written in HTML and supported by JavaScript libraries. The textual navigation menu on the left is basic HTML list-elements, the top half of the view is generated by Tableau through its JavaScript Application Programming Interface (API), and the bottom half is BIMSurfer views of the building .json data files.

General navigation in a tree-style is provided on the left-hand side, which allows the expansion of each facility and equipment class on demand. Figure 10 shows the tree for building 10400 expanded. The 3-D image also supports navigation by clicking on assets of interest.

Figure 10. UI generation for composite view.

In Figure 10, the user has selected the Composite tab, which shows the BIM view and the Energy view together in a tiled format. The user can select a different building element at any time using the menu or 3-D BIM, and all views will update accordingly.

BIM Unified Context: BIM data relevant to this demonstration is stored in a Microsoft SQL database and accessed via standard query/response techniques. The MDEI Data Warehouse (MDEI-DW) and BIM Unified Context data sources contain appropriate cross-referencing to identify and relate entities (e.g., assets and spaces). Historical time-series information is associated through the BIM to its relevant building context to enhance building and energy management tasks, analytics, and visualizations.

Honeywell's BIM Builder provides data output in the Industry Foundation Class (.ifc) format. These data files were sent to a local BIMserver (Open Source software available through bimserver.org) which provides the capability to transform the format of the data to JSON. One requirement for viewing these 3-D BIM models with BIMSurfer is a browser which supports the HTML5 Canvas and WebGL extension.

Tableau Visualizations: Visualizations are created using the Tableau Desktop application, and then uploaded to Tableau server which allows for integration in the web-based UI. Tableau has two components, Desktop and Server, which are both installed on the MDEI Server. Tableau Server was configured in the Trusted Ticket Authentication mode, which allows user authentication to occur at the web application container level.

Building Automation and Meter Data: Time-series data is supplied from existing UMCS and meters on site.

Weather Service Data: This data consists of 15 minute interval data (96 samples per day) for key characteristics of the ambient weather conditions at Fort Jackson. This data was supplied by an existing subscription service in the energy center.

5.3.4 System Integration

Information collected from control systems installed in buildings on the base is transmitted locally to the Fort Jackson energy center using the existing wireless networks, as per current site implementation.

Collected data from metering solutions, UMCS monitoring, and BIM data is integrated within an MDEI-DW (Microsoft SQL Server) installed on the MDEI Server (Dell PowerEdge R320 Server with Windows Server 2008 OS) located in the server room of the Energy Center. The path of information is one way, from existing systems that produce data to this common repository.

The Apache web server, Tableau Desktop and Tableau Server are also installed and running on the same Windows server. This server is fully contained inside the Energy Center Wide Area Network (WAN). See Figure 8 for a diagram of the system.

The DPW uses an approved wireless connection to the Energy Center to connect remote management clients. The MDEI interface was made available through this existing channel.

5.3.5 System Controls

The Dell server, which hosts all the above applications and associated data, has a single administrator account with password requirements per government and Honeywell policy.

5.4 OPERATIONAL TESTING

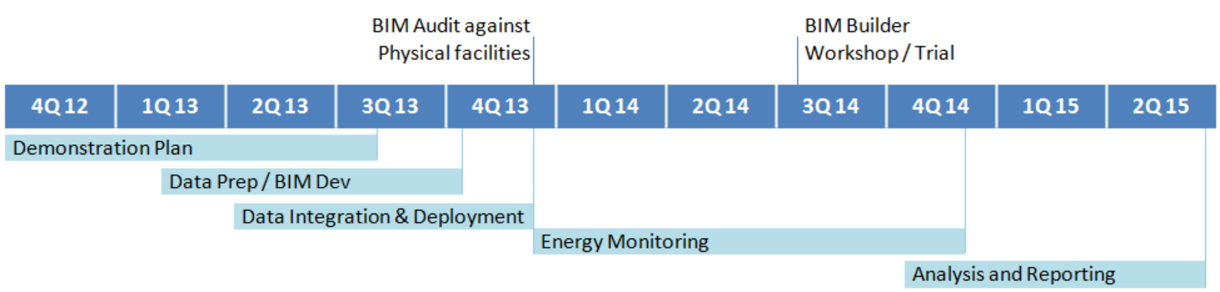

Figure 11. Timeline of pilot activities.

5.5 SAMPLING PROTOCOL

- ***Structural data:***
    - CAD data (as provided by the site or USACE)
    - Generated BIM files, as produced by Honeywell applications
- ***Metering data:*** Real-time data collection from meters and UMCS solutions were fully automated and monitored by Honeywell staff at the Fort Jackson Energy Center. The resulting volume of data was approximately 500,000 time-stamped meter records

- ***Building telemetry data:*** DCS Data from each building was collected automatically, at 6-minute intervals. The data includes more than 150M time stamped records.
- ***Third-party Weather data:*** Available in 15 minute intervals (96 samples per day) through third-party subscription.
- ***Surveys and Questionnaires:*** No formal surveys were conducted. Informal interviews were conducted with the EM and building managers to get feedback about their engagement in energy management at Fort Jackson.

5.6 SAMPLING RESULTS

Tableau dashboards were generated to summarize the number of samples collected for the past 24 hours, and then scheduled to be embedded in emails sent to registered users every morning at 5:00 a.m. local time.

During the pilot period, data sample quality was measured by verifying that the data point reported a value for the expected number of collection times in a day, e.g. for 6-minute data, 240 data values were collected.

Table 5 shows quality of data from the five buildings over the course of the pilot project. The darker green shows where the best quality occurred. Yellow cells represent data of lesser quality. Gray cells show where no data was available. The value indicates the percentage of data collected as compared to expected sampling (typically 96 samples per day at 15 min intervals).

Table 5. Percent of expected samples collected for each source in each month during pilot demonstration.

	2013					2014									
Building / Data Type	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
2450 BMS Data		100	100	100	97	100	100	100	100	100	100	98	96	96	5
2450 Electric Meter	95	16	0	1	85	100	100	100	47	0	64	100	76		
2450 Gas Meter	96	16	0	1	85	99	99	100	47	0	64	100	76		
9810 BMS Data		88	99	99	94	100	85	81	64	46	67	88	81	73	100
9810 Electric Meter	89	100	100	99	96	100	83	7	54	64	88	99	85		
9810 Gas Meter	0	0	0	0	0	0	0	0	0	0	0	0	0		
10400 BMS Data	98	63	100	100	97	100	100	97	93	100	99	91	86	99	29
10400 BTU Meter						100	100	97	92	100	100	89	100	100	100
10400 Electric Meter	99	98	99	99	96	97	100	98	94	50	50	50	50		
11000 BMS Data		35	52	52	50	52	52	51	50	52	52	52	52	52	52
11000 BTU Meter						100	100	97	92	100	100	100	100	100	100
11000 Electric Meter	13	0	0	31	95	99	98	93	95	100	100	99	99		
12000 BMS Data		33	64	83	80	83	83	80	76	83	81	80	80	80	81
12000 Electric Meter															
12000 BTU Meter						99	100	97	92	100	100	100	100	100	100

6.0 PERFORMANCE ASSESSMENT

6.1 PO 1: FUNCTIONAL BIM

The intent of this performance objective (PO) was to show that the BIM Builder software provided by Honeywell could produce output consistent with DoD expectations for information integration, and that the IFC output of BIM Builder would enable information re-use through the application of DoD tools for conversion into other formats, such as COBie. The principal measure of this analysis was the level of detail provided, and the coverage of data points expressly required by the operational use cases that were defined. The evaluation of BIM Builder's utility as a tool for knowledge extraction from CAD files consisted of three activities:

1. Generation of a BIM for each of the five facilities in the Fort Jackson Pilot using "as-built" CAD
2. Physical audit to confirm and correct the accuracy of the generated BIM against the existing facilities at Fort Jackson
3. Evaluation of the format and content of the resulting models by the team at CERL

Two other objectives are related to PO 1. PO5 discusses the efficiency of using the BIM Builder software to generate models, and PO7 discusses the overlap and transferability of this data to support BUILDER requirements. All three of these POs were substantially evaluated by the team at ERDC-CERL.

Results: BIM Builder was used successfully to extract the necessary details from CAD and produce the BIM model in IFC, and the equipment and space relationships required for ease of navigation and data integration. The resulting models were deployed in the pilot. Table 6 describes the CAD features extracted for each of the five facilities.

Table 6. CAD features extracted for five facilities.

Building	Total Area (ft^2)	Number of HVAC Assets	Number of Spaces
2450	120000	353	119
9810	37310	358	113
10400	23178	135	49
11000	290481	807	469
12000	290481	974	512

An analysis by ERDC-CERL concluded that the output of BIM Builder should be improved to ensure interoperability through the public standard mechanisms, with an emphasis on improving the encoding of building components in IFC. Honeywell plans to implement these improvements. Additional interoperability interests are discussed in Section 6.8 and further detail can be found in the Final Report.

6.2 PO 2: ENERGY INTELLIGENCE IMPACT ON ENERGY USE

The hypothesis that Honeywell has pursued in this study is that providing an integrated view of the arrangement of equipment and spaces, and the relationship between energy use and equipment behavior can lead to better insights and more effective and timely energy management interventions. By using the physical information model provided by BIM, and attaching the operational information provided by the control system, Honeywell provides an energy manager and other interested stakeholders with a ready source of rich information about how and why a building performs as it does. An example of this integrated view can be seen in Figure 12.

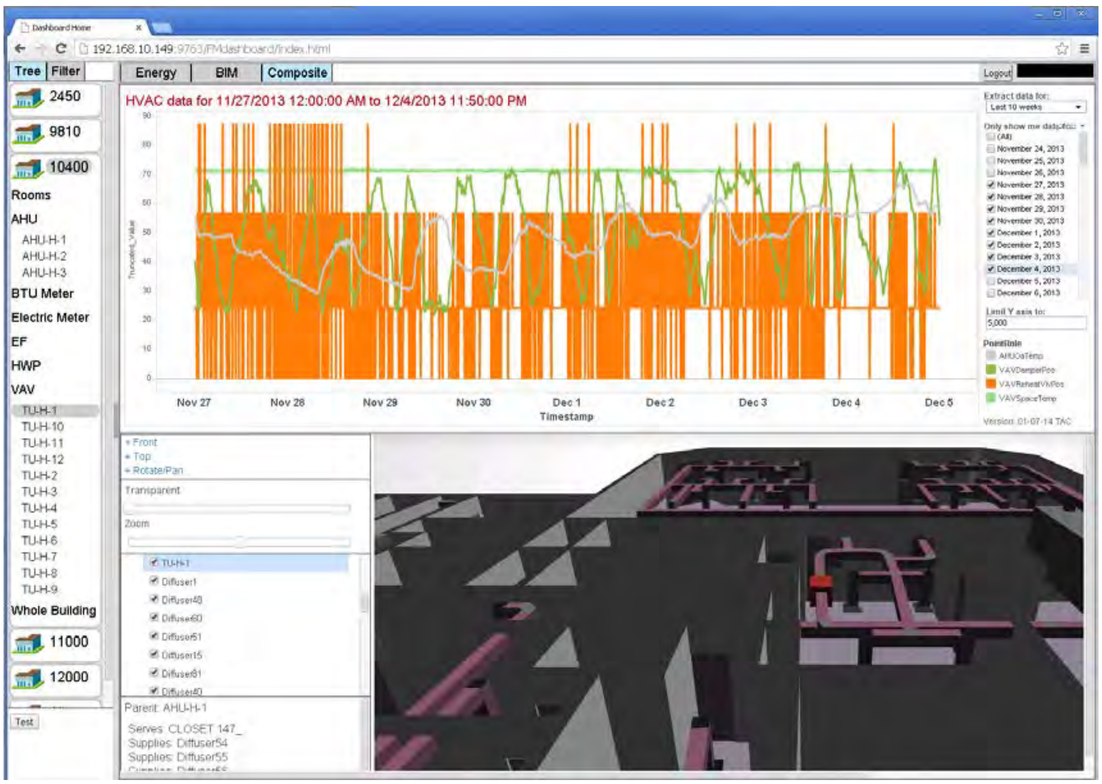

Figure 12. Example integrated display showing equipment context and behavior.

Energy Conservation Measures

The energy monitoring goals defined for this pilot demonstration were to identify occurrences of these common efficiency issues in building operation:

- HVAC equipment running when it shouldn't be
- Excessive consumption by HVAC equipment caused by the introduction of excessive or inadequate outside air
- Excessive HVAC consumption through a failure of the equipment to meet comfort goals
- Unusual patterns of operation

Results of Monitoring

The collected trend data uncovered chronic causes of inefficient operation in the monitored facilities. Table 7 summarizes the findings, which are presented in more detail in the Final Report.

Table 7. Summary of energy analysis results.

	Simultaneous Heating and Cooling	Continuous Operation	Incomplete Shutdown
Building Number	10400	2450	9810
Issues	Terminal unit behavior, including reheat and overall system operation	RTU behavior, and Gas Use for heating in vehicle bays	Scheduling anomalies
Solutions	• Improved scheduling • Retrofit improvements to air delivery to principal working space	• Improved scheduling. • Additional automation on vehicle bay IR units.	• Improved scheduling
Potential Savings (%)	18-25	15-25	15
Annual Savings	340,255 kWh	341,616 kWh	175,121 kWh
Annual Savings	1161 MBTU	1165 MBTU	597 MBTU

kWh = kilowatt hour
MBTU = one million British Thermal Units
RTU = roof-top-unit

Energy Intensity

The visualization shown in Figure 13 is available from the UI MDEI Energy dashboard. It provides a comparison of electrical energy usage demand between buildings, normalized for size (average w/ft^2).

The time span begins at March 2013 (left-most bar) and continues through October 2014 (right-most bar). Month by month, the EM can quickly see how the buildings compare.

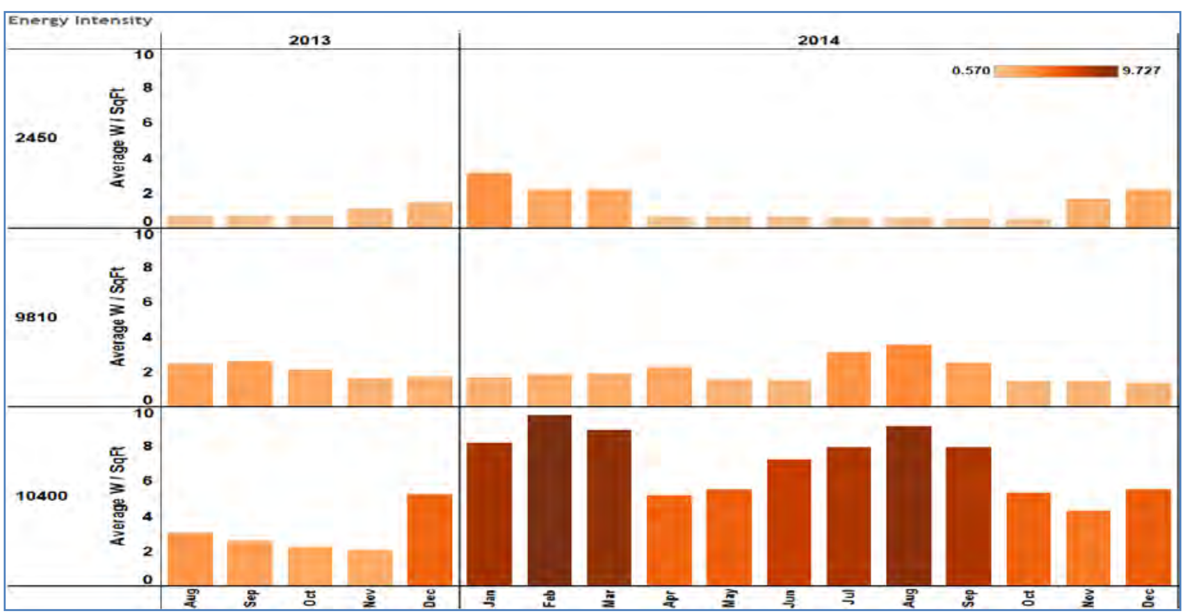

Figure 13. Energy intensity comparison using average W/ft^2.

Notes about the underlying data:

- Gas data was not available for 9810, so it is not reflected in energy intensity for that facility; 9810 has a local chiller and boiler.
- BTU data for central Hot Water and Chilled Water are factored into the figures for 10400.
- Both gas meter data and electrical are included in for 2450, which has a local boiler.
    - The heating load in 2450 applies to the full 210,000 ft^2 including vehicle bays.
    - In those months with low gas usage for 2450 (April-Oct), average cooling demand is 1.65 KW/ft^2 when spread only across the 45,000 of cooled classroom and office space. This still results in an average intensity that is considerably lower than 9810 and 10400 during the warmest months of the year.

Estimated Savings Potential in Building 2450 – Vehicle Maintenance Training Facility

Since no substantial changes were made to the operation of 2450 during the pilot period, the project team estimated savings potential from the regression analysis and observation of days that represent best performance. Using the weekend electrical baseline as a reference, and assuming a nominal 45-hour normal operating period during the week (based on interviews with the staff), a conservative estimate is overall reduction of 15 percent electrical consumption over current operating practices.

In this facility gas consumption is a significant cost of winter operations to heat the vehicle maintenance bays. This analysis shows that the heaters often run all night, though the staff has not indicated that overnight operation is typical in this class room facility. Therefore, given the observed performance, the project team estimated a potential 25 percent savings from baseline gas use on heating days, if the IR heaters are operated only as needed.

The project team observed that the building is capable of dropping back to these levels, and that a minimum reduction of 15 percent could be achieved during the cooling season, based on typical occupancy.

Estimated Savings Potential in Building 9810—Soldier Services Facility

Based on conversations with the occupants and manager, normal working hours for this facility average 45 hours per week. However, the building systems shut down briefly from roughly 6 to 8 p.m. and then start up and run continuously until roughly 6 a.m. Systems shut down for approximately one hour before resuming daytime operating parameters.

An overall savings of 15 to 20 percent is conservative based on the regression analysis and observation of operating behavior.

Estimated Savings Potential in Building 10400—Brigade Headquarters

Due to continuous air delivery to all spaces in 10400 and centralized Hot Water and Chilled Water supplies, electrical consumption in this facility is relatively flat year round. Observations of this facility are detailed in Appendix J of the Final Report, and illustrate the following behaviors that lead to inefficient operation:

- Simultaneous heating and cooling
- 24x7 operation of all spaces including classrooms
- Over cooling of many spaces
- Under-served spaces

Based on observed behaviors and regression analyses, the project team believed that the savings potential in this facility was a minimum 15 percent, and potentially as much as 25 percent when accounting for all of the factors that are leading to inefficient operation.

6.3 PO 3: IMPROVE ENERGY MANAGER VISIBILITY

In this study, Honeywell pursued the hypothesis that providing an integrated view of equipment arrangement and building space, as well as the relationship between energy use and equipment behavior, can lead to better insights and more effective and timely energy management interventions. By using the physical information model provided by BIM, and attaching the operational information provided by the control system, the project team provided an energy manager and other interested stakeholders with a ready source of rich information about building performance.

The EM was very receptive to the information that could be provided about the facility functions. Meetings were held with the EM every two weeks over a period of about two months. During that time, findings were reviewed using tools that were put in place to browse data directly. These meetings had three objectives:

- Validate the configuration of the system: Recognize and address issues with the collection and classification of the information, either with the building model or the data from the building management system

- Validate the findings: Discuss anomalies made evident in trends and possible solutions to the issues

- Train the EM in the use of the tools: Through review of the thought process the tool supports and the means to navigate from one view to another, the review sessions also served as training

For the purposes of this pilot, the EM was equipped with a workstation that could access the systems on the local, dedicated control network. This required the MDEI energy dashboard to be located in a specific location within the DPW offices where this network could be accessed. This workstation was not in the EM’s office, and the data was not readily available from the desktop. [See Section 5 for a network diagram.]

Ultimately, the EM used the system on an independent schedule and usage was tracked. The EM interacted very little with the system once it was installed, perhaps because the system was not part of the normal daily activities. With other HVAC monitoring solutions (both Honeywell and third party solutions), this data would only be accessed when something was going wrong, and HVAC managers were compelled to interrogate the control system for answers. Furthermore, the EM

could not access this information at will from his own workstation. It could only be accessed at a specific workstation with connectivity to the pilot interface.

This deployment scenario reflects the typical situation in cases where the control systems are on an isolated network, as is the case at Fort Jackson. This degree of isolation can be addressed by installing control and monitoring solutions that meet the network security requirements, or by bringing data from these systems into the secured network where it can be integrated into other tools and workflows.

It is difficult to draw conclusions from a single reference example; however, given experiences in this and related pilots, it seems that:

- By integrating the information and presenting it consistently, it is easier to recognize the anomalies identified by the data
- The typical EM at an installation as large as Fort Jackson cannot review detailed energy information on a regular basis; the volume of such information is too high
- The identification of actionable situations must be more highly automated to be useful
- If this information is to be useful and effective, it has to be more accessible and part of a regular routine
- Addressing the network isolation of energy information systems at DoD bases is critical to enabling ready access to energy managers, both on and off site

When the demonstration plan was committed to, there was still some expectation that an individual at each facility would be assigned responsibility for energy management at their site. It became obvious early in the execution that these individuals were not going to be easy to engage in the study, even if their role in the management of energy use was suitably formalized. The prevailing reasons why this study did not engage these individuals were:

- Chain of command: If there was someone assigned to this role, they are outside the management structure of the DPW, and therefore not readily available for this pilot without considerable networking with people in their chain of command.
- Changeover: The amount of movement of people through such positions, especially under the conditions at Fort Jackson, meant that the same individuals could not be engaged throughout the pilot.
- Priorities: Operations and energy management are secondary to mission. This would have made it difficult to routinely engage with these individuals.

To the extent that it was possible, the team sat down with the local manager responsible for each facility, to inform them about the project, to learn about their concerns, and gain their support for the activities.

6.4 PO 4: TRANSFERABILITY TO DOD PORTFOLIO

Potential Benefits for DoD Facilities

Detection and remedy of HVAC system performance problems in DoD buildings has historically been problematic. Energy management and maintenance resources are limited. If the MDEI methodology can provide the intended capabilities, it can automate the diagnosis of HVAC systems performance in buildings, assist in troubleshooting and diagnosis, identify problematic HVAC components, and propose remediation measures. As of 2012 roughly 205,000 buildings are owned and operated by the DoD. The question is how much of the DoD building inventory can benefit from application of BIM Builder and MDEI methodology.

Transferability

There are two critical factors that are the primary determinates for transferability to DoD facilities: the existence of a BIM for the building, and the existence of a UMCS with which a DDC system and necessary system communications and software.

The DoD Facility Inventory

The DoD Facility Inventory is described in the Department of Defense Base Structure Report (BSR). The 2012 BSR is used as primary data source for this assessment. It displays 10 Facility Classes consisting of 204,941 buildings in total. However, not all facility types are suitable for energy systems monitoring and control. Removing Family Housing and Utility and Grounds Improvements leaves approximately 176,000 buildings that are likely to be space conditioned. Details of this analysis are provided in the Final Report, Section 6.4, Table 17.

BIM & CAD in the Current Building Inventory

BIM was first required for the Army's Military Transformation (MT) program in 2008. The Army now requires BIM for all new facilities programs beginning in 2013. The Air Force has required BIM for all new designs beginning in 2010. The Navy is phasing in BIM beginning fiscal year 2015.

ERDC-CERL and Headquarters, U.S. Army Corps of Engineers (HQUSACE) estimated approximately 3 to 3.5 percent of all Army buildings built from 2007 through 2012 were developed with a BIM. Applying 3 to 3.5 percent to the DoD building inventory of 176,000 suggests roughly 6,100 BIM exist for DoD buildings as of 2012. BIM will also be developed in the future for all new DoD construction projects.

Developing a BIM as part of a building's design development is preferred. However, a BIM can be generated with the BIM-Builder from existing CAD files. The Army began applying CAD to new facilities design in 1995. Approximately 20 percent of all Army facilities were constructed post-1995. Applying 20 percent to the DoD inventory of 176,000 buildings, CAD files should exist for over 40,000 buildings.

Approximately 11 percent of all Army buildings were built 1985 – 1994 before CAD was required. These buildings will be upgraded or repurposed in the near future, and CAD files will be developed for these projects. Applying 11 percent to the DoD building inventory of 176,000 suggests over

19,000 additional buildings are likely to have, or will have, CAD files and BIM in the foreseeable future.

Therefore, CAD files now exist or will exist in the near future, and BIM can potentially be developed for up to roughly 60,000 DoD buildings, which is roughly one-third of all DoD all buildings. Furthermore, BIM will be developed for all future new construction projects. However, at this time the numbers of new construction projects throughout DoD in the near future will be relatively low.

Direct Digital Control Systems in the Current Building Inventory

The MDEI methodology depends on the existence of appropriate sensors/instrumentation along with access to that the sensor data, suggesting that a DDC system in the building is necessary, along with software and infrastructure to access the needed data. The data needs to be accessible to the MDEI.

Numerically, not all Army buildings will have DDC-grade controlled HVAC systems. A sampling of major Army installations indicates roughly 38 percent of all buildings on-post are likely to be climate controlled and large enough (at a breakpoint is 4,000 ft^2) to justify implementation of a DDC system and front-end operator workstation. MDEI would be a potential software application. Applying this 38 percent to a pool of 176,000 DoD buildings, roughly 67,000 buildings would be DDC candidates.

The sampling of the Army installations also indicates roughly 15 to 50 percent actually have DDC Systems at present. Applying this range to the DoD inventory of 67,000 conditioned buildings, roughly 10,000 to almost 33,000 buildings are likely to have DDC systems installed at present. An assumption is made that were the MDEI methodology to be applied, the necessary communication and operator infrastructure will also be installed.

Conclusions about the transferability of MDEI

While not a large portion of the existing DoD building inventory, potential application to up to roughly 33,000 buildings is not insignificant. A portion of another 19,000 older buildings would be subject to major upgrades or repurposing or conversion in the foreseeable future. These are likely to include new HVAC systems and UMCS systems, along with BIM and/or CAD files. ERDC-CERL estimates that upwards of 40,000 buildings within DoD could be suitable for the application of MDEI. While new construction in DoD buildings will be limited in number for the near future, MDEI should be applicable to all new DoD buildings as well.

6.5 PO 5: BIM TOOL EFFICIENCY

This objective focuses on the efficiency of the Honeywell BIM Builder tool for generating medium-fidelity BIM for operations on existing facilities. The Final Report includes a detailed analysis of this method versus alternative methods, as well as detailed findings for all three experiments noted below.

The assessment of efficiency was conducted in three parts:

1. The performance of the Honeywell expert user of BIM Builder was recorded during the development of the Fort Jackson models.
2. The Honeywell expert user was also timed on the creation of the BIM model for a Brigade headquarters building, which was also used in a timed trial with CERL participants.
3. ERDC-CERL resources also conducted a timed trial using experienced Revit users (separate architecture and MEP experts) modeling the same Brigade Headquarters that was used for the novice trial.

Results of BIM Builder Expert on Pilot Facilities

BIM Builder provided the best performance advantage over the prevailing method when modeling large buildings, due to the economies of scale provided by bulk extraction of like objects from the CAD sources. Figure 14 illustrates that as the building gets larger, the efficiency of modeling (ft^2 modeled per hour) increases. Figure 15 shows that the time required to model a facility in BIM Builder is not a function of the size of the facility. This makes it affordable to model any facility for operations management, regardless of size, if suitable CAD files are available.

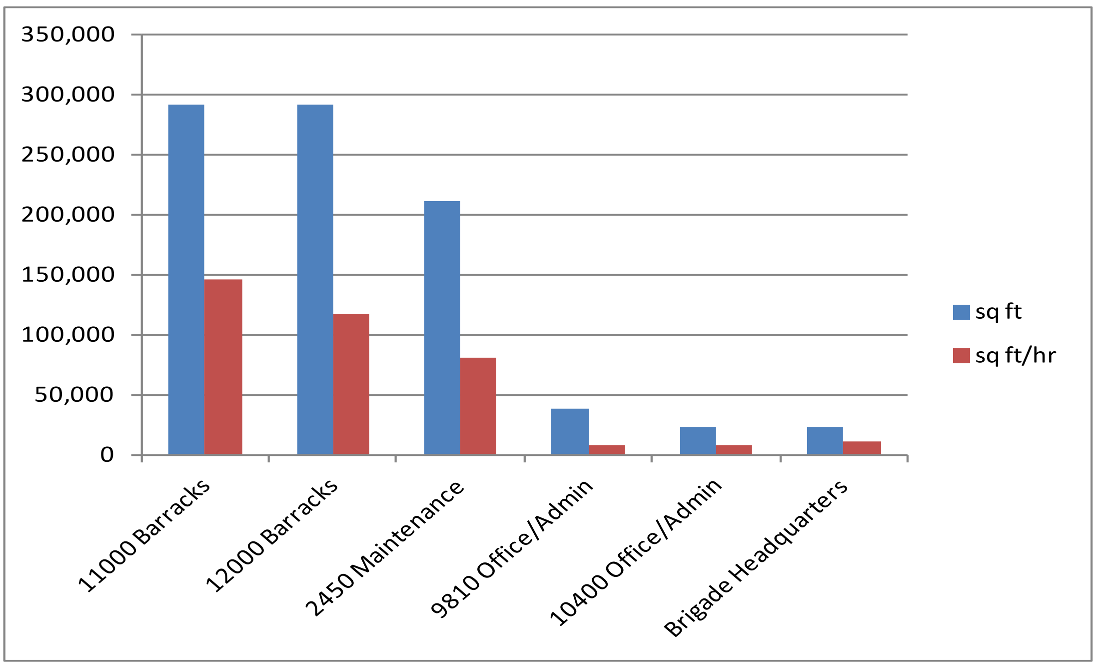

Figure 14. Modeling performance of BIM Builder Expert on test facilities.
Measured in Square Feet per Hour by Facility Size.

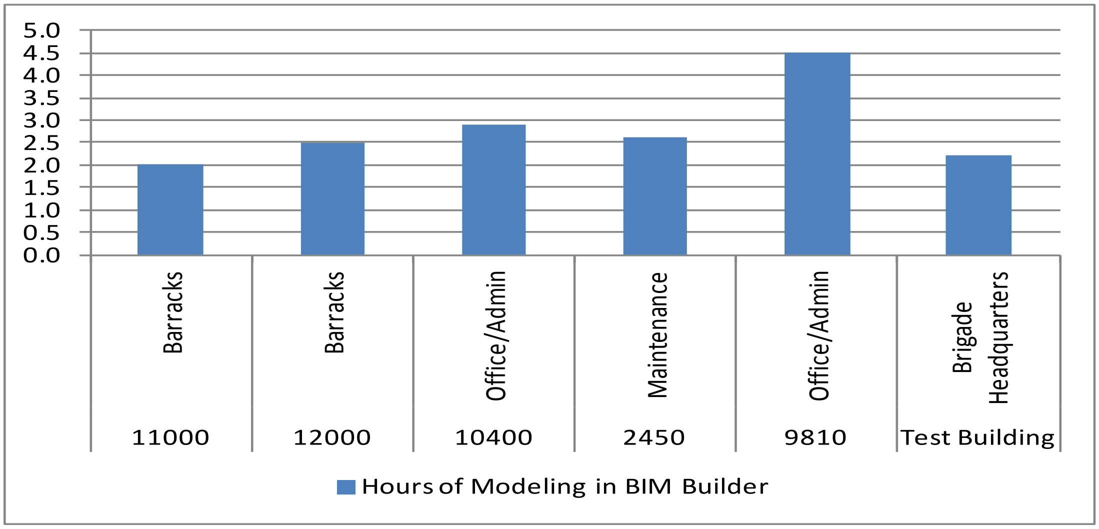

Figure 15. Hours spent on each building by BIM Builder Expert.

Results of BIM Builder Workshop, Demonstration, and Novice Performance

Hands-on testing of the Honeywell BIM Builder was completed with five test subjects at ERDC-CERL in Champaign, IL. The building selected by CERL for the demonstration and test was a Brigade Headquarters facility; comprising 22,400 ft^2 on two floors. It is a combination of open office, command and secure information space. It includes 141 diffusers, 40 variable air volumes (VAV), three air handling units (AHU), and three main supply ducts. Test subjects were familiar with CAD, but not expert with CAD or the BIM Builder tool.

The most likely skilled user would be one with understanding of the CAD methods for indicating MEP equipment by graphic and naming conventions. They would understand how MEP systems are laid out and configured. They would be competent with drawing and graphic editing tool conventions and would have familiarity with the building or style of building they are modeling. The user comments during the training and testing sessions highlight some of these desired traits.

Results

Detailed results of this test are presented in the Final Report, and are summarized here.

- HVAC object extraction: all subjects were able to complete object extraction of 98 percent or better, as compared to the expert and the baseline BIM for this facility
- Correct association of VAV units to building spaces; there was a roughly 81 percent rate of success in correct association of VAVs to the spaces they serve. This shows a slightly lower level of tool and user accuracy in correct detection of spaces
- Correct attachments of each equipment object to equipment objects upstream of it in the MEP supply relationship: four of five subjects had a greater than 80 percent success rate at generating the right system connections using the tool

The results of the test are considered promising given that the test users had not used the tool before the one day of training, were not directly familiar with the building they were using, and did not have an ideal match to the skills identified as the most likely BIM Builder skilled user.

6.6 PO 6: PARTIALLY AUTOMATED CLASSIFICATION

This objective demonstrates a capability to map DCS points, to roles and assets (equipment) using a partially-automated process which leverages semantic standards. This tool supports energy analysis, with respect to classifying points, and therefore equipment, into group behavior (roles), which helps identify the key performance indicators and attempt to associate those with the correct entity as identified by BIM, as well as standardizing how visualizations represent this data.

To support the process of matching and for the purposes of this pilot project, a discrete set of point roles were identified as relevant to energy intelligence and analysis, as well as visualization requirements.

Results

Table 8 summarizes the results of the partially automated classification of points by the AutoContext tool. The results are very positive for a few buildings, especially building 12000, which on its own, provides sufficient classification matches to satisfy the performance objective of classifying at least 500 points within four hours.

Table 8. AutoContext point role and equipment classification results.

Building	2450	9810	10400	11000	12000	Total
Total Points	542	243	650	252	861	2296
Configured Points +	262	91	84	252	847	1536
Auto-Context Correct Point Roles	205	77	23	51	653	1009
% Correct Role Classification	78.24%	84.62%	27%	20.24%	77.10%	
% Correct Equipment Classification	92.75%	91.21%	88.10%	10.32%	94.21%	
Time to Generate Point Roles (sec) ^	25	14	26	14	40	

+ Number of points that are mapped and available through the Building Control System, and utilized in this pilot
^ Total Points list used in Auto-Context application

Variability in the results stems largely from the variability in the underlying naming convention that was used to identify data in the original system. Naming conventions that reduce many of the key concepts to single characters (e.g., T for Temp or F for Fahrenheit) require additional manual processing, either in tuning the processing input parameters, or in post-processing the results.

A timed exercise was performed by a Honeywell team member and an onsite Honeywell engineer to complete the verification of roles for building 12000. The result was 126 minutes, which was well below the four hour objective.

6.7 PO 7: GAP ANALYSIS

The intent of this performance objective was to conduct gap analysis of the content and quality of data represented in the generated BIM with respect to BUILDER database, and estimate the information transfer potential.

BIM Builder to BUILDER SMS

DoD has recently mandated the use of BUILDER SMS, a web-based tool designed by CERL to assist facility managers and technicians in deciding how to best maintain their building assets on military installations. Given a BUILDER SMS business case, it is in Honeywell's interest to explore the possibility of transferring data from BIM Builder to BUILDER SMS.

First, the data fields of both tools were evaluated to determine the overlapping on data fields. The building elements were then evaluated to determine information gaps among the data stored in COBie versus the data required by BUILDER SMS. Building elements were evaluated using the ASTM International Uniformat II classification system, the format on which BUILDER SMS data is organized. A comparison with the information typically included in USACE design BIMs was also included in this preliminary stage.

BIM Builder captures information about the spaces identified in a model, as well as the assets, and also the relationships between assets and spaces so that both asset location and service dependency can be derived. Presently, there is a failing in the way that this data is presented in the two available export forms (COBie, and IFC), such that the data is not presented in the form that the current tools expect, even though that data is present.

The project team assessed the findings from ERDC-CERL and estimate that it will cost roughly $25K for the necessary improvements to the information export tools to make the output of BIM Builder fully compatible with existing DoD tooling for information interoperability, and fully compliant with current IFC standards.

6.8 EW-201260 JOINT TASK RELATED TO SIMUWATT DATA EXCHANGE

Honeywell and National Renewable Energy Laboratory (NREL)/Concept3D
Collaboration with ESTCP 201260: Electronic Auditing Tool with Geometry Capture.

OpenStudio gbXML to BIM Builder

ESTCP identified a related research program awarded in 2012 to NREL and a commercial partner, concept3d, where the objective of the program, titled *"Electronic Auditing Tool with Geometry Capture"* ESTCP 201260, is to produce a tool that may be used to develop a simple spatial model of a facility, during a standard physical energy audit in the field. The simuwatt tool is particularly attractive in cases where there is no suitable as-built CAD model to use as input. The project team explored the potential of integrating these complimentary solutions (simuwatt Energy Audit and BIM Builder) to improve the ability to generate spatial reference models for buildings without existing documentation of the architecture and assets. Each team shared data from their processes and tools, and explored the merits and challenges of combining the different approaches.

The final report contains details of the information exchange methods that were explored, but there were no tools presently available to bridge the gap. There are a few options which could be explored that would enable these tools to exchange data effectively.

Create a gbXML import plug-in for BIM Builder: The plug-in would read gbXML and translate it directly to the required data set(s) so that the basic IFC model can be constructed.

Generate a gbXML file from BIM Builder: A gbXML export tool could be added to BIM Builder so that this data could be imported into simuwatt to use in field audits.

Create an IFC plug-in for BIM Builder: An IFC plug-in could be utilized in the case where gbXML data is first translated into IFC format from another software tool, and that IFC is then read by BIM Builder.

Create an IFC import plug-in for simuwatt: If simuwatt is the preferred tool for energy performance analysis, significant time could be saved in the field by pre-loading simuwatt with an existing model of the facility. It might be helpful for simuwatt to accept IFC input as there are other sources of IFC data.

Summary

The data from these models can only be combined effectively if the DoD determines the form in which they want to manage building geometry data for the long-term. Some pros and cons are of the various format options are presented in the Final Report, Section 6.8.

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7.0 COST ASSESSMENT

This section presents a cost assessment of the MDEI technology. It provides general guidance about costs and an example life cycle cost comparison, but both costs and impact will be site-specific. Impact is based on the estimate of potential cost savings at the pilot site.

7.1 COST MODEL

The primary cost elements in a field implementation of MDEI technology are listed in Table 9. These estimates are based on start-up and maintenance of a five-building installation. Estimated costs for additional buildings are noted. Further elaboration of these cost elements and underlying assumptions are presented in the Final Report.

Table 9. Cost elements.

Cost Element	Estimated Start-up Cost	Estimated Recurring Cost (Annual)
Monitoring hardware capital costs	$50K	See Maintenance
Data services installation costs	$100K[1]	See Maintenance
Facility operational costs	$41K	$29K
Maintenance	n/a	$25K
Hardware lifetime	n/a	$25K
Operator training	n/a	$10K
Estimated start-up costs per additional building[2]	$10K	$2K
MDEI server software maintenance[3]	n/a	$50K
BIM Builder licensing[3]	n/a	$5K

[1]This cost assumes a localized data collection and data services environment such as the one piloted at Fort Jackson. The pricing model for centralized data collection at a common DoD data warehouse would be considerably different. This cost does not address Department of Defense Information Assurance Certification and Accreditation Process network certification of all the necessary software components.
[2] The cost of each additional building is non-linear. Up to some threshold, the addition of new facilities to the monitoring program does not modify the underlying cost structure. For the purposes of this estimate, the project team treated the scale factor as a block of 50 facilities per unit of infrastructure (server installation).
[3] The Honeywell tools and services fielded in this pilot are not yet formally priced for sale by Honeywell. All costs are based on the best estimate of actual installation and service costs based on experience with related products and services, as well as experience on this pilot.

All other costs are estimated as a function of normal operations and maintenance activities that might be identified or directed as a direct consequence of such monitoring.

Capital improvements to major HVAC equipment or services (e.g., replacing a chiller, for example), or building improvements (e.g., new roof) is not included as a cost of this program. It is presumed that this program would not modify capital budgets in any way, but might help to improve the prioritization of capital improvements.

7.2 COST DRIVERS

Cost drivers that affect the economics of a field implementation of MDEI technology include the following:

- The status of the data collection infrastructure at the site; Fort Jackson had an existing infrastructure for meter data and building control data collection that could be leveraged to keep initial costs lower.

- The availability of CAD data sources for the facilities on the site, and the relative quality of those original CAD files.

The impacts of the above cost drivers are site-specific. These issues should be investigated as part of an energy and economic study in planning an application of MDEI. Such a study (to identify the energy savings opportunities, assess the economic potential, and assist in planning the implementation) can be performed by Honeywell Building Solutions (HBS). Funding for an installation of MDEI would be available through Military Construction (MILCON) or other DoD energy improvement programs.

7.3 COST ANALYSIS

The Life Cycle Cost Analysis covers the initial cost for creating the BIM for five buildings at Fort Jackson totaling 766,450 ft^2 and the maintenance of the BIM, the initial system configuration and ongoing system licensing, and the estimated cost of implementing typical energy conservation recommendations for building control, such as the cost of installation or relocation of sensors to improve the performance of the system.

As this product has not been fully commercialized, exact pricing figures are not yet available. The project team estimated a likely price for five buildings, based on experience with similar offerings:

- The initial system configuration is estimated at $100,000
- Yearly system licensing is estimated at $50,000
- Additional facilities, up to 50 total (on the same basic infrastructure), can be accommodated at an incremental cost adjusted for building size and condition

The project team used a conservative figure for data quality maintenance, which covers extending the model with new information sources as new use cases and new data requirements are identified over time. Experience shows there is significant return on the continued investment in data quality.

BIM Generation and Maintenance Costs: This study results suggest that modeling with prevailing tools may average $1.00 per 100 ft^2 on average, regardless of building size. By comparison, BIM Builder can help users to achieve an efficiency of $0.50 per 100 ft^2, regardless of building size. Once the BIM is generated, it needs to be maintained. The project team estimated a cost of roughly $10K annually to maintain the accuracy of the models that are in use.

Building Control and Equipment Maintenance: The project team estimated costs incurred to respond to equipment maintenance and control changes to improve performance.

Capital equipment and repair/replacement costs are anticipated to be the same (no change in overall budget) with or without the BIM-enabled energy analysis, barring other institutional changes to maintenance practices. The outcome of such monitoring helps to prioritize the projects that are budgeted.

Energy Monitoring and Analysis: The expectation is that the DoD will monitor energy in-house, and anticipate that this task requires a minimum of two hours per month per building, estimated at

a cost of $6,000 per year for five facilities. If this task was contracted out to a third party, or centralized in the DoD costs will likely be different.

The National Institute of Standards and Technology (NIST) Building Life Cycle Cost (BLCC) analysis estimates a 1.27 kWh/ft^2 annual savings through implementation of the control and sensor recommendations identified by the MDEI. The project team estimated that this savings could be applied to roughly 40,000 of the DoD facilities (see Section 6.4 of the Final Report), or roughly 13.4 percent or 129 million ft^2. This amounts to roughly 163,830 MWhr in annual energy savings.

The results of the life-cycle cost analysis are summarized in Table 10 and further detailed in the Final Report. For each energy source, a 20 percent savings estimate was used, calculated against 2013-2014 actual consumption by the subject facilities; this savings target is substantiated in Section 6.2.

Table 10. BLCC Environmental Conservation Investment Program (ECIP) summary results.

Annual Energy and Cost Savings Estimate for the Pilot Facilities			
Electricity Annual Energy Savings:			8,992 MBtu
Electricity Annual Cost Savings:			$152,261
Electricity Demand Annual Cost Savings:			$39,037
Natural Gas Annual Energy Savings:			4,822 MBtu
Natural Gas Annual Cost Savings:			$53,727
Annual Non-Energy Costs			
Non-recurring MDEI BIM Generation Cost:			$3,832
Annually Recurring Costs:			$78,600
	Economic Study Period		
ECIP Results	**5 years**	**10 years**	**20 years**
Electricity Discounted Cost Savings	$775,988	$1,505,509	$2,795,005
Electricity Demand Discounted Cost Savings	$198,951	$385,989	$716,596
Natural Gas Discounted Cost Savings	$306,754	$639,772	$1,304,680
Discounted Recurring Costs	($598,800)	($1,135,585)	($2,040,537)
First year savings	$120,658	$121,042	$121,234
Simple Payback Period (in years)	0.93 years	0.93 years	0.93 years
Total Discounted Operational Savings	$679,061	$1,391,854	$2,771,911
Savings to Investment Ratio (SIR)	6.03	12.36	24.62
Adjusted Internal Rate of Return (AIRR)	43.28%	29.89%	19.25%

MBtu = one million British Thermal Units

This BLCC calculation was performed based on the cost estimates and benefits (20 percent energy savings) with respect to the pilot structure; that is the benefit to apply this technology to five facilities, totaling 766,450 ft^2; this translates to roughly $0.16 cents saved per ft^2 in the first five years. Start-up costs are not linear with respect to additional facilities; that is, the software infrastructure costs will scale for many more facilities without significant additional investment in infrastructure. For an incremental startup cost of $50K for five additional facilities of similar footprint, the energy savings in the first year would double.

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8.0 IMPLEMENTATION ISSUES

During the course of the program the project team encountered the following concerns that represent potential hurdles, opportunity for improvement, or unaddressed needs that might be addressed by future programs.

8.1 INFRASTRUCTURE AND INSTALLATION

As discussed earlier, this program was meant to leverage the existing data infrastructure at sites where data collection from both metering and DCS solutions was already in progress. Unfortunately, maintenance of such systems is not always part of an on-going contract, and the infrastructure was not as robust as anticipated.

- The DoD should be concerned about the long-term maintenance of investments in monitoring
- Teams should be advised to budget for unexpected gaps in the data collection infrastructure
- It was sometimes necessary to deal with multiple vendors having active contracts at the site to resolve simple issues or track down the warranty status of pieces of the infrastructure to discuss repair

8.2 DATA COLLECTION AND SECURITY

- Activities such as the development of the Army Meter Data Management System (MDMS) will hopefully streamline data collection for enhanced energy management across the DoD.
- Information security is likely the leading issue to be addressed to extract the value that can be gained through integrated energy management environments such as MDEI
- Information interoperability for enterprise level energy management is a nascent issue that is being addressed by several major standards bodies. Much work is needed here to enhance the current state of the art

8.3 BIM FOR OPERATIONS

- No solution is useful unless it becomes part of work practice. Energy visualizations of any type need to be presented directly in the working environment of the Energy manager or other end user to deliver value. This relates back to data collection and network security practices around the collection of control and energy data.
- Existing tools are geared toward designers and the construction process. When 3-D models are put in the hands of new end users in facility management, new navigation requirements are uncovered. Current visualization tools for BIM are not well suited for these new use cases. Movement through the model is too free-form, and requires some skill.

- When these models start to be used, a seamless way to keep them up-to-date will be necessary to ensure that they remain living and vital with respect to current facility conditions. This requires both new processes and tools and a cultural ecosystem that encourages maintenance of the information.

9.0 REFERENCES

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APPENDIX A

POINTS OF CONTACT

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